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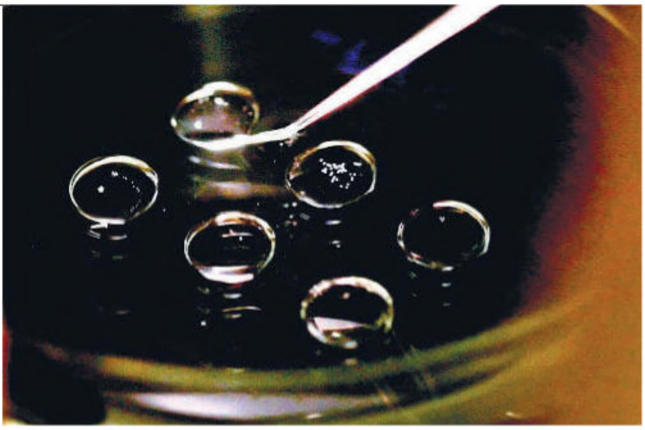

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AWARDS

Dame Carol Robinson, Professor of Chemistry at Oxford University, invented a ground-breaking method for studying how membrane proteins function, which play a critical role in the human body.

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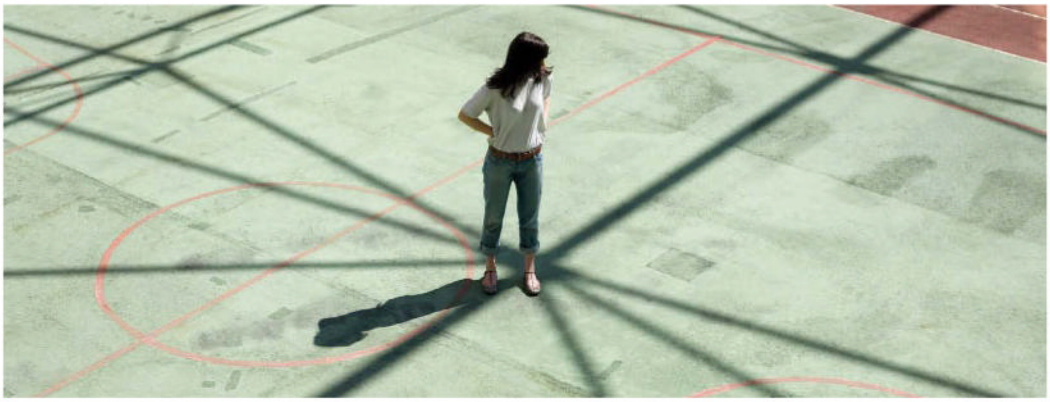

CLAIRE COCANO/PICTURETANK

Critical thinking

The toolkit of scientific literacy is needed beyond science

HERE'S a game to play next time you catch the news headlines. Count how many would dissolve away or be markedly different if the people writing them had evaluated the evidence more critically. Your count will probably be alarmingly high.

We have a long tradition of allowing civic affairs to be settled by persuasive rhetoric. That is inadequate for our modern society. Science and technology shape our world and, as a society, we need to make well-reasoned and scientifically literate choices about everything from genetic engineering to geoengineering.

But many of the tools used to make science-heavy decisions are also needed to properly evaluate a much broader range of subjects: in particular, critical thinking and numerical analysis. A basic grasp of statistics and probability, for instance, is key to judging the risk from terrorism, say, or how to invest your money (see page 30).

But the desired combination of scientific literacy and critical thinking remains rare in public discourse. Perhaps that is because we hope children will learn to evaluate claims rationally if we teach them science. That works for some, but all too often the reaction is: "I'll never need to use this once I've left school."

That's being taken up by the Programme for International Student Assessment. The PISA tests, which attempt to compare student performance around the world, are always controversial, but their central concern is sound: "What is important for citizens to know and be able to do?" This year, they are focused on the scientific literacy of 15-year-olds from more than 70 states and regions around the world. But then what exactly is scientific literacy?

> **"Using rhetoric to settle civic affairs is inadequate for running our modern society"**

PISA's lengthy definition begins with "an individual's scientific knowledge and use of that knowledge to identify questions" and ends with "willingness to engage in science-related issues, and with the issues of science, as a reflective citizen".

We have made progress on the first part of this definition. In 1996, a survey found that more than half of the US population didn't know Earth orbits the sun; few even knew what that might mean. But more recent polls suggest that US scientific literacy has improved greatly. A Pew survey released in September concluded that "most Americans can answer basic questions about several scientific terms and concepts": that Earth's core is its hottest part, for example, or that uranium is needed for nuclear energy and weapons.

But mastery of facts alone is not enough for the internet age. Much of the copious online rhetoric is more viral than factual, so it is just as important that we know how to evaluate sources of information, and how to tell correlation from causation, and opinion from fact – in matters both obviously scientific and otherwise.

This is where we're falling short of the tail end of PISA's definition. Kids who don't see the point of science often lack chances to hone their critical thinking toolkits, particularly their numerical sides. And textbook knowledge doesn't translate easily to practice: cell biology can seem very remote when deciding who's really worth listening to about vaccination.

This shortfall is being addressed: in UK schools, for example, the Twenty First Century Science GCSE module covers issues of relevance to everyone, whatever their scientific ambitions (or lack of them). But our societies still have a long way to go when it comes to reading between the headlines – or rewriting them. ■

Climate link to UK floods

WE'RE out of our depth. Climate change is implicated in the record-breaking rain that caused major flooding in the UK this week.

The army has been deployed to help rescue efforts and tens of thousands of homes were left without power as Storm Desmond battered Scotland and the north of England. More than 340 millimetres of rain fell in 24 hours in the Lake District, breaking a record of 316.4 mm set in 2009.

It is difficult to draw a link with climate change because the UK climate has always been variable, says David Ramsbottom of HR Wallingford, a consultancy that advises the UK government on flood defences. "But the current wisdom is that storminess is increasing and therefore these types of events are likely to increase," he says.

"It is impossible to say that a particular flood event is or isn't caused by climate change," says Seth Westra at the University of Adelaide in Australia. "But climate change does appear to be making the heavy rainfall events that cause floods more frequent and intense, and so should be considered to be part of the story."

Ramsbottom says the UK needs to improve its warning systems, and ensure new developments are flood resistant. Friends of the Earth says the government is failing to do so.

But even with bolstered defences, many people in flood-prone areas won't be protected from extreme events, and some places will become uninhabitable, Ramsbottom says.

REUTERS/PHIL NOBLE

Deep trouble

Venus rendezvous

IT'S a reunion of astronomical proportions. A damaged satellite that missed its rendezvous with Venus was finally sent into orbit around the planet exactly five years late, after the team came up with a successful hack to get it back on course.

In May 2010, the Japanese space agency JAXA launched Akatsuki to study Venus's strange atmosphere. In particular, it was hoped the satellite could find out why extreme winds race across the planet at up to 400 kilometres per hour, and possibly give insight into what Earth might look like in a billion years' time.

> "A successful hack got the damaged Japanese satellite back on course, exactly five years late"

But disaster struck on 7 December 2010. When the satellite attempted to fire its thrusters, instead of entering Venus's orbit, it cruised off into space, falling into orbit around the sun. Later analysis suggested the thruster nozzles had been damaged, causing a safety valve to cut them off early.

Over the next few years, JAXA tested the various thrusters on board, and found the main ones unusable. So in a last-ditch effort, the team decided to change the functioning of its secondary thrusters – normally intended for steering – and attempt a second entry.

In October 2011, the team commanded Akatsuki to dump all the fuel for the broken thrusters, making it lighter. Then they reprogrammed the secondary thrusters to put the satellite on course to rendezvous with Venus in 2015.

On Monday, the moment came. The thrusters fired for 20 minutes, and Akatsuki now appears to be in orbit around Venus, JAXA said in a statement. However, it will take a few days to properly determine the orbit, the agency says. There are also some concerns about the condition of Akatsuki's instruments, which might have been damaged by heat on the sunward journey. JAXA's next update should be released on 9 December.

Cool drinks on Mars

DRINK up. The first moisture farm on Mars will be part of a mission blasting off in 2018.

Earlier this year, results from NASA's Curiosity rover suggested pools of liquid water form at night just beneath Mars's surface, before evaporating during the day. An instrument called HABIT designed to measure and test this process has now been approved for ExoMars, a joint mission between the European Space Agency and Russia to send a rover and lander to Mars in 2018.

HABIT will use salts to absorb 5 millilitres of water from the atmosphere each day, and can hold 25 ml in total. That might not sound much, but if the process works, it can be scaled up to provide water for future crewed missions.

Meanwhile, the seismometers on NASA's InSight lander, due to launch in March, have developed a fault. NASA and CNES, France's space agency, are fixing a leaky vacuum chamber and still hope to make the planned launch date.

Emissions set to fall in 2015

JUST a blip? Emissions from burning fossil fuels and industry may fall slightly in 2015 – for the first time in the absence of an economic recession – although overall emissions will probably still rise.

Over the past decade, fossil fuel emissions have been rising faster than ever, growing by an average of 2.4 per cent each year. But in 2014, the rate of growth slowed to 0.6 per cent, and may drop by 0.6 per cent in 2015 (*Nature Climate Change*, doi.org/9s7). This is mainly because China is burning less coal, thanks to efforts to reduce air pollution and an economic slowdown.

But total emissions as a result of human activity, including deforestation, probably rose. And 2015 is likely to be just a blip, before rises resume. "I would not think this is a trend at all," says Corinne Le Quere of the University of East Anglia, UK. "It is very unlikely that this is the peak in global emissions."

Cash for qubits

THE quantum computing race is hotting up. IBM has been working to wipe out errors in quantum hardware, and its efforts have just won a major boost – funding from the US Intelligence Advanced Research Projects Activity (IARPA).

> **"Laying out the error-prone qubits on a grid allows them to act as a single, well-behaved unit"**

Quantum computing is still hampered by the fragility of quantum bits – qubits – which are easily affected by heat and electromagnetic radiation. To stabilise them, IBM is taking qubits made from superconducting chips and laying them out on a grid. This allows the error-prone qubits to act as a single, well-behaved unit, known as a logical qubit.

"What we've done thus far is to demonstrate some of the concepts of error correction and detection," says IBM's Jerry Chow.

They need about 20 ordinary qubits to create one logical qubit, but packing qubits close together will be tricky. "When you put many of them together, you don't know that they are going to work the same way as when you just have one," Chow says.

IBM isn't alone. Google, too, has hired researchers to develop quantum hardware. "It's more of a competitive field now," says Chow.

QILAI SHEN/PANOS PICTURES

Thank China

STR/AFP/GETTY

No more antibiotics for you

Going global

THE final drug has fallen. Bacteria carrying a gene that allows them to resist our last-resort antibiotics, called polymyxins, have been found in Denmark and China.

The discovery means bacteria that cause common gut, urinary and blood infections in humans can now become resistant to all antibiotics available – making some infections incurable without new ones.

> **"Bacteria that cause common infections in humans can now become resistant to all antibiotics"**

Last month, Yi-Yun Liu at South China Agricultural University in Guangzhou and colleagues discovered a gene for resistance to colistin, the most common polymyxin, in microbes found in livestock, meat and humans.

As the gene can spread between bacteria, the team predicted it could soon go global. Unknown to them, it already had. Frank Aarestrup at the Technical University of Denmark in Lyngby searched for it in a Danish database of bacterial DNA found in people, animals and food. He found it in one human infection and in five samples of imported poultry. Ominously, bacteria with the gene were also resistant to other antibiotics, including penicillin.

We don't know where the gene originated, but it could be China, where large amounts of colistin are fed to livestock.

A UK government review, released this week, calls for global targets to reduce antibiotic use in food production, which will be vital if life-saving medicines are to be kept effective.

Maternal deaths

SUICIDE is now a leading cause of maternal death in the UK.

An analysis of all women who died either during pregnancy or up to one year after giving birth between 2009 and 2013 reveals that overall, maternity-related deaths are declining in the UK. Compared with 2003, the number of deaths caused by complications during pregnancy has fallen.

But there was no corresponding fall in deaths from indirect causes, such as pre-existing conditions that pregnancy can make worse.

Suicide accounted for 1 in 10 of the deaths. The rate is lower than in the general population, but shows perinatal mental health services aren't improving as fast as other maternal healthcare.

Of the 101 cases of suicide, only 15 women had had contact with perinatal mental health services, even though around half had a history of depression.

60 SECONDS

Famine fear in Ethiopia

Ethiopia is in the grip of its worst drought for 30 years, fuelled by an extreme El Niño event - by some measures the biggest on record. The World Health Organization says the situation is likely to worsen, and is mobilising drugs and resources for 8.2 million needing food assistance, and 400,000 children who are facing severe malnutrition in 2016.

Hippopota-meat eater

We think of them as vegetarians, but hippos routinely eat the carcasses of animals such as elephants, impala, wildebeest - and other hippos, which may harbour deadly bacteria. This could explain why they have higher death rates from anthrax than ungulates that only eat grass, such as zebras and buffaloes (*Mammal Review*, doi.org/9tm).

Last Enceladus close-up

NASA's Cassini probe is set to make its final fly-by of Saturn's frozen moon Enceladus on 19 December. In October the spacecraft made a deep dive towards the moon, sampling from a plume of water and ice shot out by the ocean hidden below. NASA is still analysing the results to look for signs of alien microbes.

Swimming sperm

Like us, you can split sperm into lefties and righties. All sperm rotate their tails anticlockwise. When they move through fluid, this should mean they can only move in a leftwards direction, but researchers have seen that about 50 per cent of sperm are capable of turning right. They do this by craning their necks to counteract the force from their tails (*PNAS*, DOI: 10.1073/pnas.1515159112).

Chimps on Skype

It's not your average FaceTime. Musician Peter Gabriel is devising an experiment to see if chimpanzees can communicate with each other over via videoconferencing. He plans to collaborate with a chimp rescue centre in Dorset, UK, next year.

Green light for edited embryos

World's leading geneticists decide to allow gene editing of human embryos

Anna Nowogrodzki, Michael Le Page

SANDY HUFFAKER/BLOOMBERG VIA GETTY

THE most controversial type of gene editing has got the cautious nod of approval. Far from calling for a ban on the technique to alter human embryos, an international summit has effectively endorsed the idea. While it is too soon to try it out, basic research should be allowed, alongside a debate on how we should use the technology. This puts us on a path that could see germline gene editing happening in people in some countries just decades from now.

Gene editing, the practice of making precise changes to the genome, has already been used to treat a handful of people. The start of another human trial, to treat the blood disease haemophilia B, was announced at the summit. However, these trials don't involve tinkering with embryos, so the changes can't be inherited.

So-called germline editing is far more controversial, because the changes are passed on to future generations. A statement released by the summit's organising committee said it would be irresponsible to attempt germline editing in humans until it can be done safely, and until there is wide agreement on what it should be used for. This point is still a long way off.

"However, as scientific knowledge advances and societal views evolve, the clinical use of germline editing should be revisited on a regular basis," said the committee, which contained both biologists and ethicists.

> **"As science advances and societal views evolve, the use of germline editing should be revisited"**

The statement, released at the end of the International Summit on Human Gene Editing in Washington DC last week, calls for everyone from scientists to members of the public to start discussing what constitutes acceptable use of the technology. Countries should then introduce regulations that allow those applications while banning others considered unacceptable.

For instance, some might approve of germline editing to reduce a person's risk of Alzheimer's disease, but draw the line at changing skin colour.

Gene editing has been possible for decades but used to be extremely difficult and expensive. The development of a revolutionary technique called CRISPR a few years ago changed everything. It is so cheap and easy that thousands of labs are already using it for research.

Earlier this year, one team in China published the results of its attempt to modify human embryos using CRISPR, for research purposes only. Several other groups were rumoured to be doing similar work. While such studies are legal in many countries, concerns about this kind of work led to calls in March for a voluntary ban on editing human embryos.

This is what prompted the national academies of science in many countries – including the US, UK and China – to organise last week's summit.

While germline editing human embryos is still a long way off, rapid progress is being made with other kinds of gene therapy – using genetic techniques to treat disease. A company called Sangamo in Richmond, California, has already used an older form of gene editing – based on zinc finger nucleases rather than CRISPR – to treat people with HIV. Immune

THIS TIME IT'S PERSONAL

Ronald Cohn wants to use CRISPR (see main story) to edit the genes of his friend's 13-year-old son, but he's running out of time. The boy, Gavriel, has Duchenne muscular dystrophy, a genetic disease in which muscles degenerate. Life expectancy with the condition is about 25 years.

Gavriel was diagnosed at age 4. He has already lost the use of his legs but still has some movement in his upper body, and uses a manual wheelchair. Cohn, a clinician at The Hospital for Sick Children in Toronto, estimates he has three years to develop and test a CRISPR-based treatment before he won't be able to help Gavriel. This week, his team described how they grew Gavriel's cells in a dish and used CRISPR gene-editing techniques to correct the mutation that causes his disease (*The American Journal of Human Genetics*, DOI: 10.1016/j.ajhg.2015.11.012).

Cohn says he plans to test the approach in mice with Gavriel's exact mutation before he applies for permission to try it on Gavriel. The research in human cells is so new that he has many unanswered questions. "That's what I'm losing sleep over."

Should the approach work in mice, there are ways to get it into human cells. A gene therapy trial for muscular dystrophy is already under way and involves delivering the corrected gene inside an inactivated virus. This could be repurposed to deliver the CRISPR system instead.

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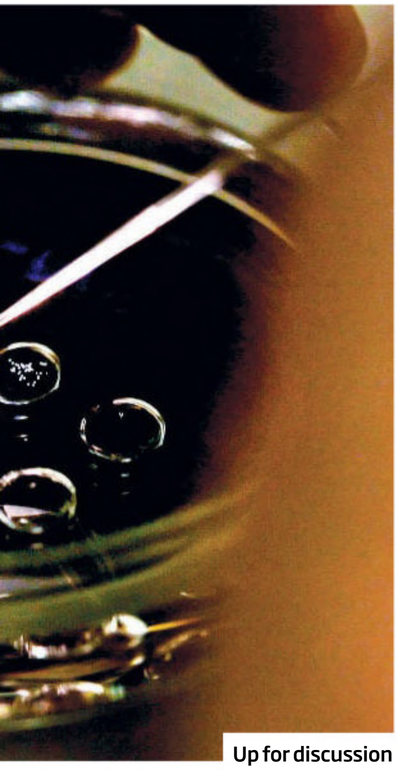


Up for discussion

cells were removed from the body, edited to make them resistant to the virus and then replaced, with promising results.

Now Sangamo hopes to cure haemophilia B, a clotting disorder that can result in spontaneous internal bleeding, with the help of customised zinc finger nucleases.

Viruses will deliver genes coding for the nucleases and a corrected copy of the faulty gene to the liver. If the gene is inserted in the right place, the organ should start producing lots of clotting protein.

That's what happened in mice and primates, and the team now has the go-ahead to try it in adults. If it proves safe, children could get the treatment too – allowing them to run around and play normally.

CRISPR gene editing is so new it has not yet been tried for gene therapy, but numerous animal trials are already under way. Editas Medicine, a biotech firm based in Cambridge, Massachusetts, could launch the first human trial. Last month it announced that its trial to treat a rare form of blindness could start as early as 2017. ■

INSIGHT UN climate summit

Could optimists seize the day in Paris and beyond?

OPTIMISM can be disorientating. But though little is yet agreed in Paris as the UN climate talks enter their final days, nobody seems to doubt a deal will be struck. As UN secretary general Ban Ki-moon said, the agreement in Paris would "send a clear signal that the low emissions future is inevitable".

By itself a deal won't be enough to keep the world below 2 degrees of warming. But, say optimists here, the message it sends will unleash a torrent of investment in renewable energy. That in turn will prompt R&D to deliver better and cheaper technology – and the impetus for tougher targets on emissions cuts later on.

This kind of talk can be catching in a pressure-cooker conference of sleep-deprived delegates. And it might just help seal the deal here later this week.

The mood extended to the science on Monday, with news of a probable fall in global carbon dioxide emissions from fossil fuels in 2015 – for the first time in the absence of economic recession. This is thanks to one-time climate bad-boy China shutting so many coal plants that its emissions fell almost 4 per cent.

Nobody imagines global emissions have peaked, though. But if China can go green, any country can. Maybe even India, now the world's fourth largest emitter. Its insistence on industrialising by burning coal is the nearest thing to a wet blanket here in Paris. "India is where China was in 1990," said Corinne Le Quéré at the University of East Anglia, UK, who presented the new emissions assessment.

But optimism is drowning out such fears. A host of leading bankers and investors – bosses of Allianz and ABP, to name two – showed up promising to divest their portfolios of fossil fuels and reinvest in solar and wind. While governments fuss over billions to fund green development, bankers are talking trillions, noted UN Environment Programme director, Achim Steiner, as he announced a Portfolio Decarbonization Coalition.

But there are grounds for pessimism, too. Most of the 186 national emissions pledges submitted here for the period 2020 to 2030 – the bedrock of the agreement – are vague and riddled with promises conditional on rich nations stumping up funds. Crucially, none will be legally binding.

> **"Whatever happens at the Paris summit, optimists say the world is in a transition to zero emissions"**

Rich nations remain tight-lipped on funding vital adaptation measures to help poor countries cope with the ravages of extreme weather in the future. That is a potential deal-breaker, because African nations are unlikely to sign up to a deal without those funds.

Diplomats can always cut deals. But what would a truly successful outcome for the climate look like? Most agree on three essentials. A system to police the national pledges is vital. There must also be a way to regularly review and strengthen any agreed targets in case the climate forecast gets bleaker or energy technologies get cheaper. Current pledges at best push the world towards 3 degrees. As Ban put it this week, "we must go much further."

Equally important for many is setting ambitious long-term goals for after 2030. Moving to a zero-emissions world is a popular option. As is targeting 1.5 degrees of warming, rather than the agreed 2 degrees.

This is heady stuff. But when the governor of the Bank of England, Mark Carney, shows up to declare that, whatever happens in Paris, the world is "in a transition to a net zero [emissions] world", it looks like something is afoot. Maybe, just maybe, the optimists are right. ■

STEPHANE MAHE / REUTERS

How low can we go?

KIEKE VAN MAARSCHALKERWAART

It takes brains to catch a dolphin

Orcas herd and ambush dolphins

Bob Holmes

THEY'VE definitely earned their name. A pod of killer whales already famous for its frighteningly effective hunting methods has been seen tricking dolphins into an ambush.

Orcas have been filmed hunting dolphins before, but never using such a complex group-hunting technique. This pod, which lives off the coast of Patagonia, Argentina, came to the world's attention when members of the group were spotted intentionally beaching themselves to capture baby sea lions, then refloating when the next wave rolled in.

The ringleader then and now is a female that researchers have named Maga. They watched from boats as the orcas encountered their dolphin prey then set up the ambush.

"It seems to be coordinated," says Mariano Coscarella of Argentina's National Scientific and Technical Research Council in Puerto Madryn. "Maga is within the group of killer whales following the dolphins, then she disappears."

He thinks Maga swims ahead and waits for the unsuspecting dolphins, because the next time the researchers see her is when she suddenly head-butts one of the dolphins, throwing it into the air and injuring or killing it.

Researchers have now seen the behaviour at least five times, including twice since Coscarella and his colleagues published their initial findings in May (*Aquatic Mammals*, doi.org/9sn). No one has looked for the behaviour in other orca pods, says Coscarella, but it would not surprise him if it were more widespread.

The technique is complex because Maga, the "catcher", has to hide in order for the ambush to work. In practice, that means waiting quietly without echolocating while the pod drives the dolphins towards her.

"It takes coordinated behaviour, and really good knowledge of their environment. I think that makes this technique quite interesting," says Coscarella. "They drive the prey towards a catcher, just as chimps do."

Chimpanzees notoriously go on coordinated group-hunting trips for red colobus monkeys, in which some individuals chase the monkeys towards others waiting to catch and kill them.

"The technique is complex because the catcher has to hide in order for the ambush to work"

The only other mammals known to use such herding and ambush tactics are humans, which puts the orcas in a small and elite group, Coscarella says.

Most marine mammal biologists already think orca hunters are as sophisticated as any chimpanzee. They are known to pass hunting methods from generation to generation, resulting in the formation of cultural traditions.

Orcas in polar regions work together to make waves that wash seals off ice floes, while those in Australian waters are known to cooperate to separate humpback whale calves from their mothers.

All this knowledge is culturally transmitted, says Jeff Higdon, a marine mammal biologist based in Winnipeg, Canada. Herding and ambush hunting fits easily into this rich cultural repertoire. "Given the level of cooperation we see with these animals, it doesn't terribly surprise me," says Higdon.

So is Maga a Thomas Edison among orcas, unusually adept at invention? "It's certainly possible," says Higdon. "It's clear that this pod has figured out some pretty amazing skill sets."

On the other hand, says Coscarella, Maga may just be an older whale who's been around for a while and picked up some skills along the way. There could be many more orcas out there that are equally inventive. ■

PICKY EATERS, STEALTH HUNTERS

What's your pleasure? Orca hunting techniques and food preferences are passed from generation to generation, so different pods often develop their own specialisations.

This is evident along the Pacific coast of North America, where groups with different cultural traditions frequently coexist in overlapping locations. Some pods live primarily on fish, especially salmon, while others prefer to catch seals and other marine mammals.

The fish-eating pods are known as "resident" populations, because they range across a limited area, dependably visiting the same locations. The "transient" mammal-eaters, in contrast, range widely and unpredictably. Transient pods also tend to be smaller and less vocal than residents, perhaps partly because hunting mammals requires more stealth.

Dark matter could spawn Borg-like stars

"YOU will be assimilated." In *Star Trek,* members of the strange and sinister race known as the Borg would utter this threat as if one. Their linked behaviour could be echoed in space if dark matter exists in a particular form - one that can build stars in which every particle is in the same state at the same time.

Dark matter is thought to account for 80 per cent of the matter in the universe, but hardly interacts with ordinary matter. This means it cannot be observed directly, so its constituents remain a mystery.

One theory suggests that it is made of hypothetical particles called axions. Unlike the protons, neutrons and electrons that make up ordinary matter, axions can share the same quantum state. They also attract each other via gravity, so they clump up.

Those two properties mean that the clumps form a Bose-Einstein condensate (BEC) - a type of matter in which all the particles occupy the same quantum state, according to Chanda Prescod-Weinstein at the Massachusetts Institute of Technology and her colleagues. "They act like one super-atom together," she says.

But the clumps are prone to falling apart. "The configuration the axions want to settle into is not one giant BEC," she says. Instead, they end up as smaller clumps called Bose stars.

These would have formed when the universe was a mere 47,000 years old, and should survive to this day, she says. They would still be BECs and would end up relatively small - the size of the dwarf planet Ceres, and about 20 times as dense (*Physical Review D*, doi.org/9s5).

Although they do not shine, Bose stars could make it possible for us to observe dark matter, if they are orbiting a pulsar. Under the right conditions, the pulsar and the axions would interact to produce radiation we can pick up, says Prescod-Weinstein. Anna Nowogrodzki ■

LARA WERNET/ NOVARC IMAGES/ALAMY STOCK

Ouch, for most of us

Woman 'enjoys' her very first sensation of pain

A WOMAN has felt pain for the first time aged 39, following an experiment that could lead to powerful new ways to treat painful conditions such as arthritis.

The woman was born with a genetic condition that means she cannot feel pain, but a drug normally used to treat drug overdoses enabled her to feel the pain of a laser beam on her skin – a sensation scientists say she quite enjoyed.

Only a handful of people around the world are born unable to feel pain. These individuals can often experience a range of injuries when they are young. Babies with the condition tend to chew their fingers, toes and lips until they bleed, and toddlers can sustain more knocks, tumbles and encounters with sharp or hot objects than normal. Many die at a young age.

The disorder is caused by a rare genetic mutation that results in a lack of ion channels that transport sodium across sensory nerves. Without these Nav1.7 channels, nerve cells cannot communicate pain. After this was discovered, researchers rushed to make compounds that blocked Nav1.7 channels, thinking they might be able to stop pain in people with a normal pain response.

"It looked like a fantastic drug target," says John Wood at University College London. "Pharma companies went bananas and made lots of drugs." But while a few compounds had some success, none brought about the total absence of pain seen in people who lack the channel naturally.

"A drug normally used to treat overdoses allowed her to feel the pain from a laser beam on her skin"

To find out why, Wood and his colleagues studied genetically modified mice missing Nav1.7. These animals feel no pain either – they show no reaction when their tails are exposed to extreme hot or cold temperatures, for example.

A closer analysis of the rodents' nerves showed that mice lacking Nav1.7 had a huge increase in the expression of genes responsible for opioid peptides, the body's natural painkiller. The mice seem to be making more of these pain-relieving peptides, which might explain why people missing the channel also don't feel pain.

If that were the case, figured Wood, a drug that stops opioid peptides working may reverse the disorder. Sure enough, when the team gave mice naloxone – which blocks opioid receptors and is used to treat overdoses of morphine and heroin – the animals could feel pain again.

What's more, when the team gave the drug to their female volunteer the effect was the same. The woman, who wishes to stay anonymous, says she hopes that the drug could be used to treat any children she might have with the same condition.

Wood isn't sure whether this will be an option, since long-term use of naloxone could have side effects. The opposite approach, however, may help to treat pain, he says. When his team gave normal mice Nav1.7 channel blockers together with opioid drugs, they managed to stop them feeling any pain (*Nature Communications*, doi.org/9sr).

The mice in this experiment felt as little pain as GM mice missing the Nav1.7 channel, says Wood. He has taken out a patent on the use of the two drugs for pain relief.

Kenji Okuse at Imperial College London believes the findings may change the way doctors think about treating pain conditions, but need further examination. "Opioids and Nav1.7 blockers could provide much stronger analgesics, but they will not necessarily be better for patients," he says. "If we take the combination therapy route, people would have to take opioids throughout the lifetime, which is not a welcome thing."

Jessica Hamzelou ■

Dwarf planet Ceres is a long way from home

IT'S an invader. Shiny spots and minerals on the surface of Ceres suggest that the asteroid belt's largest object may have been born in the outer solar system, far from its current abode. This also hints that our current classification of comets, asteroids and planets is too simplistic.

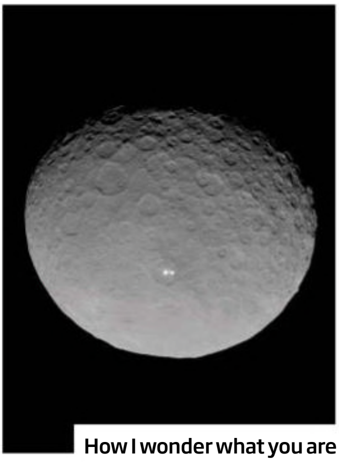
At 950 kilometres across, Ceres is considered a dwarf planet like Pluto, despite orbiting in the main asteroid belt between Mars and Jupiter. When NASA's Dawn spacecraft arrived at Ceres in March, it saw that most of the dwarf is as dark as fresh asphalt, but that there are lighter spots in craters, which range from the brightness of concrete to that of ocean ice.

New measurements suggest that the bright regions are mostly made of icy salt deposits, says Andreas Nathues, lead investigator for Dawn's camera team at the Max Planck Institute for Solar System Research in Munich, Germany.

A large crater called Occator has an especially bright pit, which probably contains water ice that vaporises as Ceres rotates into sunlight. The vapour produces haze clouds that appear and disappear during Ceres's 9-hour day.

That makes Ceres the first large body in the asteroid belt to show such comet-like activity, blurring the line between comet and asteroid.

The Dawn team thinks the ice originated beyond the solar system's "snow line", where water molecules condense. In the early solar system, this would have been several hundred million kilometres farther from the sun than Ceres's current location, suggesting that the dwarf planet was born in the land of comets and migrated inwards later (*Nature*, 10.1038/nature15754).



NASA/JPL-CALTECH/UCLA/MPS/DLR/IDA

How I wonder what you are

Other observations support this idea, says Maria Cristina De Sanctis of the Italian National Institute of Astrophysics in Rome. Using Dawn's spectrometer, she and her colleagues detected that minerals called ammoniated phyllosilicates make up about 10 per cent of Ceres's surface. For these minerals to form, ammonia had to be incorporated as the dwarf planet formed – and ammonia ice is also only stable at the temperatures beyond the snow line (*Nature*, 10.1038/nature16172).

Jupiter, Saturn, Uranus and Neptune probably moved a lot in the solar system's early days, which could have sent objects like Ceres hurtling closer to the sun, says Chris Russell, Dawn's principal investigator.

"Ceres is right at that transition zone, where we're moving from predominantly rocky bodies to outer solar system objects that are predominantly water ice," says Shane Byrne at the University of Arizona in Tucson. Its mix of comet-like and planet-like characteristics adds a new dimension to the debate about how to define a planet. Rebecca Boyle ■

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JOEL SARTORE

The hunt is on for the deepest cave

Stephen Ornes

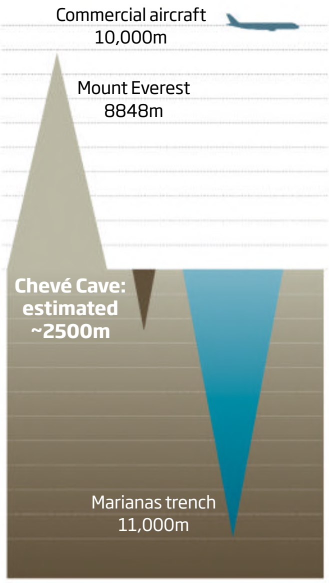
HOW low can you go? Dedicated deep cavers plumb the depths for an answer, and a newly announced expedition may just get to the bottom of it all.

For decades, cavers have competed informally to find the world's deepest cave, pushing the boundaries of science along the way. It's a perpetual quest – they can never truly know if they have found the absolute deepest. Bragging rights have bounced from cave to cave, but since 2004 the record has been 2191 metres, held by the Krubera Cave in the western Caucasus mountains, which is also home to the world's deepest land animal, a springtail.

But Bill Stone may be about to break the record. The veteran caver and inventor has announced that he is planning a 2017 expedition to the Chevé Cave system, a sprawling supercave in the Oaxaca region of Mexico, whose tortuous tunnels underlie an area twice the size of Manhattan.

Planet's extremes

Chevé Cave in Mexico is suspected to be the world's deepest. It is still dwarfed by the tallest mountain and the deepest ocean trench



STEPHEN EGINOIRE

Are we there yet?

It's not just the thrill of breaking records that drives exploration – scientific inquiry also matters. Caves are little-understood but important component of karst aquifers, which provide drinking water to hundreds of millions of people. Their steady climates also make them promising hunting grounds for well-preserved fossils, and mineral deposits can provide records of past changes in climate. For biologists, they promise to reveal new – and often bizarre – species.

"To me, and to most others on the team, Chevé is the world's most fascinating exploration puzzle," says Stone. "It's the last terrestrial frontier."

Stone isn't alone in thinking Chevé may break the depth record. "It's still possible that the deepest cave will be in the Americas, even deeper than Krubera," says Bill Steele, another veteran caver. He is now co-leading a series of expeditions to Sistema Huautla, a vast cave system that lies within sight of Chevé, on the opposite side of a canyon carved by the Santo Domingo River. Sistema Huautla is the current deepest cave in North America and drops some 1545 metres from its entrances.

Steele says Chevé has the "proven potential" to capture the title. In 1990, caver James H. Smith, Jr, dropped 7 kilograms of dye into the water at one of its entrances. The green water emerged in the canyon and spilled into the Santo Domingo after dropping over 2547 metres. If Stone and his expedition can follow the water, Chevé will beat Krubera.

But that's a big challenge: while the dye suggests a path exists, it has to be traversed by people to beat the record. "It doesn't count if you just send a dye through a cave system… any more than you can say Mount Everest was climbed the first time somebody saw the summit," says Steele.

"It's still possible that the deepest cave will be in the Americas, even deeper than the Krubera"

Going deep into Chevé is a complex operation for which Stone says he will need between 60 and 70 cavers. His strategy is to look for a route past a boulder collapse that blocked further exploration back in 2003.

The appeal of the unknown and the element of surprise is what keeps Stone and others going. "You can still climb unclimbed peaks in the world, but you can also study them on Google Earth before you go," says cave diver Zeb Lilly. "You can dive the ocean depths, but those have been mostly mapped by sonar [and] it's cost-prohibitive to do deep ocean exploration. On a budget, though, you can explore areas underground no one has ever seen."

And it's not just depth that matters. Steele and fellow caver Tommy Shifflett have organised a series of annual expeditions to explore horizontal offshoots of the Sistema Huautla that past cavers ignored as they raced to the bottom. This year's expedition was the second of 10 they have planned.

The expeditions have already turned up new species of tarantulas and scorpions, as well as bones thought to belong to extinct Pleistocene-era mammals, including a bison and a giant ground sloth. "It's a matter of being thorough, of doing all the various studies that should be done when you're exploring an area never reached before by humans," says Steele. ■

FIELD NOTES Kourou, French Guiana

Pathfinder blasts off to test Einstein

Sam Wong

THE timing was, relatively, perfect. The European Space Agency's LISA Pathfinder spacecraft took off from Kourou in French Guiana at 01:04 local time on 3 December, one day later than planned due to a technical issue with the Vega rocket that carried it into orbit.

This meant it just missed the 100th anniversary of Albert Einstein's publication of his general theory of relativity – whose predictions scientists hope to test with instruments like those on board. But the team was happy to sacrifice the auspicious date for a risk-free launch.

"We've waited 100 years for the anniversary of Einstein's equations," says Paul McNamara, the project scientist at ESA. "What's one more day?"

I joined a group of 40 scientists working on the mission who travelled to French Guiana for the big day. ESA has launched its satellites from this corner of South America governed by France since it was formed in 1975. It's a perfect location: it's close to the equator, which means rockets get extra velocity from Earth's spin, and there is open sea to the north and east, so there are two safe directions in which to launch. "Kourou is a wonderful place to launch a satellite," says McNamara.

The Guiana Space Centre is vast, its buildings and launchpads sitting among 700 square kilometres of forest inhabited by monkeys, jaguars, sloths and other fauna. It's also the launch site for more than half of the commercial satellites in orbit.

LISA Pathfinder is hoping to solve a delicate problem. It will take two gold alloy cubes, with sides just 46 millimetres long, and release them in free fall inside the craft, isolated from all external forces except gravity. The aim is to show that we can measure their positions with exquisite sensitivity, picking up deviations of 10^{-12} metres. Doing so would make it possible to detect gravitational waves, faint ripples in space-time that, according to Einstein, emanate from interactions between massive objects like neutron stars and supermassive black holes.

The launch was dogged with worries about the engine freezing and the threat of thunderstorms. Thankfully, as take off approached, the skies were cloudy but calm. In the control room, about 50 staff sat in front of a large screen with clocks and panels showing the status of the rocket. Behind them, an audience of scientists, engineers and dignitaries watched through glass walls.

From the terrace outside, the lights of the Vega launchpad were visible 11 kilometres away. When the countdown reached zero, a bright glow lit the tops of the trees and the bottom of the clouds. As it rose, the rocket soon passed behind clouds, but reappeared as it headed east over the Atlantic Ocean. After about 30 seconds, a low rumble passed through the control centre, like a foreshadow of the gravitational waves that will shake LISA's gold cubes.

Three stages of the rocket burned their fuel and detached as planned in the first 7 minutes of flight. The final rocket stage separated an hour and 45 minutes after launch, and soon afterwards the control room confirmed that the spacecraft was in a stable orbit facing the sun. Only then could the team finally celebrate.

> "A low rumble passed through the control centre, like a foreshadow of the gravitational waves"

Rather than the whooping and fist-pumping familiar from mission control rooms in films, the moment was greeted with polite clapping, raised thumbs and a few handshakes. The mission chiefs gave speeches. Then the team headed outside for a celebratory rum cocktail in the warm night air.

"It's quite surreal to see it happen after working on it for so long," says McNamara. "It was so fast. I just want to watch it again!"

The team at the European Space Operations Centre in Darmstadt, Germany, is now guiding LISA Pathfinder through six complex manoeuvres to widen its elliptical orbit around Earth. With the final burn of its propulsion module, it will cruise for six weeks to the Lagrange point L1, where gravitational forces balance to keep it in a stable position between Earth and the sun.

They might have missed Einstein's anniversary, but he would no doubt have been pleased to see scientists testing what to him was only a thought experiment. "I think he would be happy," says LISA Pathfinder principal investigator Stefano Vitale at the University of Trento, Italy. "He didn't believe this would ever be possible." ■

SAM WONG

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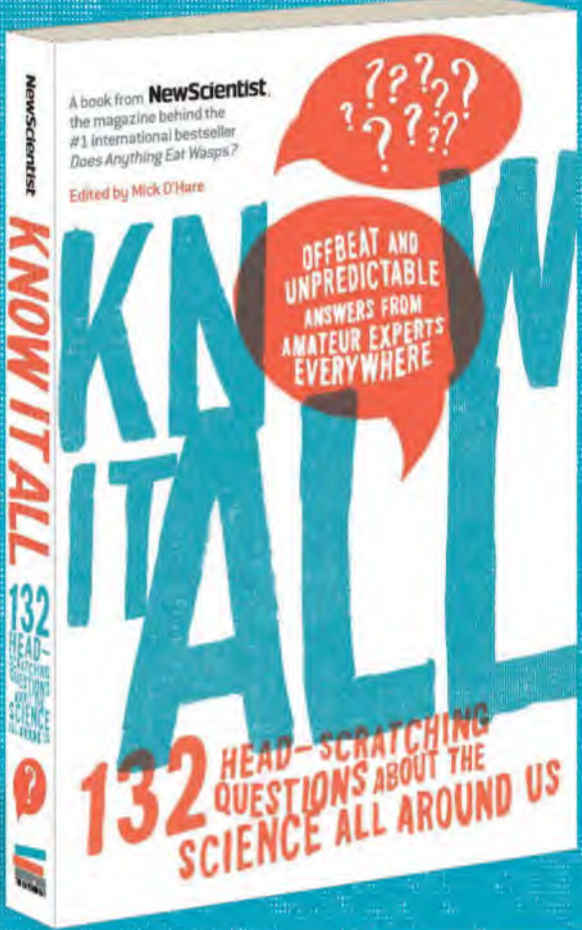
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Northern Lights make surprise journey south

THINK you have to trudge to Sweden or Alaska to see the northern lights? Well, not this year.

Typically only seen near the North Pole, the aurora borealis has been lighting up the skies over northern US states and central Europe in recent months. Now citizen science project Aurorasaurus is making it easier to know when to run outside to take in the spectacular sky show by combining Twitter data, peer verification tools and a real-time alert system.

This year has been a stormy one for the sun, which is at the peak phase of its activity cycle. As a result, its belches of geomagnetic radiation have been particularly potent. That solar wind interacts with Earth's atmosphere to create colourful displays near the poles.

Aurora predictions are based on a model developed by the NOAA, using satellite data on solar wind intensity. But citizen reports show that this year the aurora is visible much further south than the model suggests.

Aurorasaurus combines these sightings with NOAA's system to provide more accurate predictions. "This is the first time the citizen science observations are being used in a concerted effort to track the aurora in real time," says Kasha Patel, who worked on Aurorasaurus.

Beyond alerting enthusiasts, the data will be used to better understand how the interaction between the solar wind and Earth's magnetic field causes the aurora.

Planetary pairs could share microbes

THEY started it! Neighbouring planets could throw rocks at each other, spreading life across a solar system.

In our solar system, planets are spaced quite far apart. But some exoplanet systems found by NASA's Kepler satellite have planets with tightly packed orbits. In the Kepler-36 system, for example, an outer planet circles its star just 10 per cent further out than its known inner sibling.

Those planets inspired Jason Steffen of the University of Nevada in Las Vegas and his team to simulate what would happen to systems in which two worlds shared the habitable zone, a region around a star with the right temperatures for liquid water.

They found that these planets could exchange rocks easily, potentially spreading life from world to world and back again (arxiv.org/abs/1511.09211). As the rocks wouldn't have to travel far to reach another planet, the crash-landing could happen at slower speeds, reducing the chances that microbes would be vaporised.

"You can imagine the biological family tree having roots and branches on both planets simultaneously," Steffen says.

Such rock-throwing isn't rare: Earth has been hit by rocks from the moon and Mars.

Are cafe-going birds our old pals?

NEXT time a bird tries to steal your food, don't scare it away – you may destroy an ancient relationship.

These birds may just be doing what their ancestors have been doing for millions of years, says Paul Haemig, an animal ecologist at the Governing Board of Jönköping province in Sweden.

He visited 80 cafes and restaurants in southern Sweden, recording thousands of visits from our feathered friends. He found outdoor dining is most attractive for the birds, as is slow service, in particular tardy plate-clearing and relaxed staff.

Yet of more than 500 bird species in Sweden he saw only 13 at cafes. These gourmands belong to five groups, which may have long ago evolved to dine alongside humans and even our ancestors (*Biodiversity Data Journal*, doi.org/9rc). "It looks suspiciously like a very old association," he says.

Climate explains lake's fish record

THE poster child for evolution may have finally revealed its secret. More than 1000 closely related but different species of cichlid fish live in Lake Malawi in south-east Africa – more than in any other lake in the world.

"They are remarkable," says Christopher Scholz at the University of Syracuse in New York.

But no one knew why there were so many. So Scholz's team examined sediment records from the lake covering 1.3 million years, and found that over this period the water levels dropped by more than 200 metres around 24 times, altering habitats. They conclude that the diversification was driven by the variation of water levels, caused by changing climate (*PNAS*, DOI: 10.1073/pnas.1512864112).

Can men pass on 'fat' genes?

NOW there is even more reason to watch your waistline. A man's weight seems to influence gene activity in his sperm, which could leave his children predisposed to obesity.

So far, research into how obesity passes between generations has focused on mothers and their diet before or during pregnancy. But a new study suggests that the father's health may also be important.

Romain Barrès at the University of Copenhagen in Denmark and his colleagues found striking differences in the sperm from 13 lean and 10 moderately obese men. Specifically, they discovered a pattern of genetic markers in the sperm of obese men involved in the control of genes associated with appetite and brain development. These patterns were absent in lean men (*Cell Metabolism*, doi.org/9sq).

It's unclear whether these markers may influence the weight of future children. Most markers carried in sperm are erased during the fertilisation process, although some research suggests a small percentage can slip through the net.

"The results add to the body of evidence that we are not just products of 'what our mothers ate', but also 'what our fathers ate'," says Susan Ozanne at the University of Cambridge.

IAN HOOTON/SPL/CORBIS

Black holes have a size limit – of 50 billion suns

EVEN gluttons can't eat forever. When black holes at the hearts of galaxies swell to 50 billion times the mass of the sun, they may lose the discs of gas they use as cosmic feedlots.

Most galaxies host a supermassive black hole at their centre. Around it is a region of space where gas settles into an orbiting disc. This gas can lose energy and fall inwards, feeding the black hole. But these discs are known to be unstable and prone to crumbling into stars.

Theoretically, a black hole could grow so big that it swallows up the stable part of the disc and destroys it. However, no one thought that black holes would grow so big that they could do this. "It didn't occur to us to worry about it, because the mass required was so large," says Andrew King of the University of Leicester, UK.

But that's changed in recent years. The heaviest black holes we've now seen have a mass up to 40 billion times that of our sun. That fact prompted King to calculate how big a black hole would have to be for its outer edge to keep a disc from forming. He came up with the figure of 50 billion solar masses (arxiv.org/abs/1511.08502).

Without a disc, the black hole would stop growing, meaning 50 billion suns would be about the upper limit. The only way it could get larger is if a star happened to fall straight in or another black hole merged with it. Neither process fattens them up as well as a gas disc. "Unless you merge with another monster, you'll make almost no difference to the black hole mass," King says.

Laser camera can see around corners

NOW there is nowhere to hide. A camera that detects individual photons can track objects moving around corners, even when they are completely obscured from view. The device could be used for search-and-rescue missions, or installed on cars to detect oncoming vehicles.

The camera is the brainchild of Daniele Faccio's team at Heriot-Watt University in Edinburgh, UK. It can log the position of a photon in a 32-by-32 grid at20 billion frames per second. To see around corners, they first fire a laser at the floor. The light bounces off the ground and produces a spherical "echo" of just a few photons – normally too faint to see, but detectable by the ultra-sensitive camera.

Part of the echo travels around the corner, bouncing off "Terry"– a 30-centimetre-high foam human model on a moving track. This creates another echo, which eventually reaches the camera.

To pinpoint the object and distinguish it from walls, the team has to send out 67 million laser pulses per second and monitor how the signal changes as the object moves (*Nature Photonics*, DOI: 10.1038/nphoton.2015.234).

TONY KARUMBA/AFP/GETTY IMAGES

Resistant TB beaten in half the time

GET me a treatment and make it snappier. A new drug regime halves the time it takes to treat multidrug-resistant tuberculosis and has fewer side effects than other therapies.

The disease can be cured with a two-year drug regime, but only a quarter of the 480,000 people estimated to have the disease get diagnosed. Of these, just 50 per cent are cured, in part because the regime is so harrowing. Patients have to take a dozen powerful antibiotics and have daily injections for eight months. Side effects can include loss of hearing and liver damage.

The new multidrug-resistant TB regime includes many of the same drugs but lasts only nine months. Early results from 507 people undergoing treatment in nine African countries suggest it has a cure rate of about 80 per cent.

The regime has far fewer side effects because it takes less time, and costs are reduced by a third, says Arnaud Trèbucq of the International Union Against Tuberculosis and Lung Disease, who announced the results at the Union World Conference on Lung Health in Cape Town, South Africa.

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After handshakes, we sniff people's scent on our hand

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This suggests that handshakes might transmit chemical signals

You won't believe you do it, but you do. After shaking hands with someone, you'll lift your hands to your face and take a deep sniff. This newly discovered behaviour – revealed by covert filming – suggests that much like other mammals, humans use bodily smells to convey information.

We know that women's tears transmit chemosensory signals - their scent lowers testosterone levels and dampens arousal in

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Driven to action

App comrades unite

With ever more people engaged in on-demand work, **Aviva Rutkin** discovers how they're organising online to win greater rights

IT WAS a strike, but not as we know it. At midnight on 1 December, about 100 workers in New York City logged out of the Uber app on their phones in protest over a pay cut at UberRUSH, a delivery service run by the ride-sharing giant. One post on the Facebook page they created to rally the strike and list their demands read: "All we are asking is that Uber treats us fairly."

Those couriers aren't the first to feel the pinch from the gig economy (see "Gigging by numbers", opposite). Also called the sharing economy, it is made up of companies like Uber, Taskrabbit and Airbnb, their success founded on forgoing the traditional workplace in favour of labour and services sourced through smartphones. People who work via these apps are classed as independent contractors rather than full employees. They are also isolated from each other and from their companies.

"A lot of these start-ups and apps are using tech and an app-based platform to distance themselves from the people carrying out the work," says Margaret Dewhurst. Since 2011, she has been a bike courier in London for same-day delivery services like CitySprint or Deliveroo. "It's not what it's cracked up to be, all these apps. You have to do so much more than a normal job and get so much less security and perks."

Earlier this year, Dewhurst joined in a campaign organised by the Independent Workers Union of Great Britain, a London-based group representing "the unorganised, the abandoned and the betrayed". In October, it successfully lobbied courier company Gophr to commit to paying on-demand workers a living wage.

> **"With all these apps, you do so much more than a normal job and get so much less security and perks"**

The idea of sourcing labour online as and when needed has its roots in Amazon's Mechanical Turk service. Founded in 2005, long before smartphones really took off, it lets people earn small sums by completing online tasks – categorising images, say – for paying clients. It's also where gig-economy workers began organising, via the online forum Turker Nation. Kristy Milland, its community manager, says Mechanical Turk was designed "to isolate workers". Turker Nation offers a virtual water cooler where they can meet each other, share tips and air grievances. Turkers also rely on tools like review network Turkopticon to flag problematic tasks or clients.

Companies that have followed Amazon's example are seeing their workers organise too. Last year Uber and Lyft drivers in California teamed up with a local union to form the California App-Based Drivers' Association. Other cities have experienced Uber strikes like the one in New York. Facebook has become one of the main platforms for labour activism – even the employees of US retail giant Walmart have a Facebook page dedicated to improving their conditions.

Software as boss

Gig workers frequently complain about a lack of communication between themselves and bosses – a problem compounded by the fact that their immediate "boss" may well be an algorithm.

Min Kyung Lee at Carnegie Mellon University in Pittsburgh, Pennsylvania, has interviewed Uber and Lyft drivers to try to understand what it's like to be bossed around by software. She found that some struggled with the way it assessed their willingness to take work.

At Uber, for example, a driver's acceptance rate should not be below around 80 per cent. But there's no opportunity for drivers to point out that a passenger they rejected had been flagged on worker forums for bad behaviour, or for female drivers to explain that they were uncomfortable picking up someone with no profile picture late at night. The star-rating system was another bone of contention. Some drivers thought passengers didn't understand it and thus unintentionally gave low scores.

San Francisco photographer Anna Vignet, who briefly did deliveries on request via apps Postmates and DoorDash, also complained about task-assigning algorithms, saying they left her with lots of downtime between assignments, or sprang an impossibly far address on her. Calls to the companies' helplines went unanswered. "Given that these companies can't deliver food without us couriers, it's remarkable how unfinished their support services are," she wrote.

Is there scope to tailor apps more closely to the needs of crowdsourced workers? Maybe, says Lee. Platforms like Uber could assess customer reviews subjectively, rather than just taking the star rating as gospel. She's also toyed with the idea of an "altruistic metric" that scores workers for traits other than efficiency.

There is another option: leave and build a better workplace. Last month, a conference at the New School in New York City discussed ways to return power to distributed, app-bound workers. One way would be to set up cooperatives such as Stocksy, a picture agency owned by its contributors, and the driver-owned Transunion Car Service, a taxi company that launched in New Jersey in March. Transunion promises its drivers perks like shares in the firm, plus healthcare and retirement benefits.

Milland says she is intrigued by the idea, although she can foresee legal and financial obstacles. She envisions a platform where all workers can access support and training, vote on new initiatives, and receive rewards and promotions for their efforts. "If you have people in power within the co-op who are workers and have been there, you'll see a different service," she says.

> **"Facebook is one of the main platforms for labour activism - even Walmart employees are using it"**

The inherent imbalance between workers and employers in the gig economy has caught the eye of government officials. In July, the US Federal Trade Commission held a workshop exploring the associated "competition, consumer protection and economic" issues.

In September, the US House of Representatives held its own hearing. Dean Baker, co-director of the Center for Economic and Policy Research, a think tank in Washington DC, testified that regulations to protect traditional workers need modernising to cover the new world of work. "If the sharing economy is used as a way to circumvent them, then it will impose substantial costs on society," he said.

These are the early salvos in a battle that is just getting started. The speed and efficiency of online communication is already shaping the future of work. Now, workers are beginning to push back. ■

GIGGING BY NUMBERS

In the brave new world of the so-called gig economy, anyone can sell services online: car rides, lodging, home repairs, even dog-sitting. Already 17 of the companies that make this possible are valued at $1 billion or more, including Instacart for grocery deliveries, Lyft for taxi rides and Transferwise for overseas money transfers.

Uber is one of the biggest, valued at $62.5 billion by some estimates. The number of active drivers it has in the US doubled every six months for two years, reaching 160,000 at the start of this year. Airbnb is another big hitter. Worth perhaps $25 billion, it claims to offer more than 2 million rooms and properties to stay in worldwide.

But the money most people earn by selling services via these platforms isn't itself enough for them to live on. A report issued by Bloomberg in June found that 68 per cent of gig economy workers earn less than half of their total income in this way.

ONE PER CENT

Tennis, only better

Grab your racket, lace up your shoes, and step onto an augmented reality tennis court that tracks your every move. This is the promise of Swiss start-up Technis. The company embeds tracking technology in the court surface, which can be used to make automatic line calls, or measure player performance around the court.

> "By 2026 we will have ubiquitous, human-quality translation among all European languages"

Ten-year prediction from Chris Bishop, Managing Director of Microsoft Research in Cambridge, UK

Woolly typing

Knitting scarves is old hat. Researchers in Japan and France have knitted a keyboard that you can wear on your sleeve. It's made of polyester fibres coated with conductive material. When you type on its 10 keys, the material registers your touch and transmits the signal through a USB port. Knitting the keyboard makes it flexible, so it can stretch when you move your arm (*Advanced Materials*, doi.org/f3j6s9).

TECHNIS

Super-literate computers

Software will soon speed-read and understand, finds **Hal Hodson**

IN A lab next to the river on New York's Upper West Side a computer will soon start reading. It is part of a cadre of computers that are learning to read more like humans, helping us digest and understand society's huge volumes of text on a large scale.

Called the Declassification Engine, it will comb through 4.5 million US State Department cables from the 1930s to the 1980s – everything the department has declassified so far. It's more than any human could read, but the software will analyse the lot, mapping social connections and looking for new narratives about the behaviour of US diplomats and officials abroad in the 20th century, says Owen Rambow, a computer scientist at Columbia University, which runs the Declassification Engine.

"A cable might talk about a meeting with the foreign minister of Turkey," says Rambow. "If we could extract social networks from these cables then we can study how the networks of the US changed over time. In time of crises do these networks contract or expand?"

The Declassification Engine isn't the only computer with the ability to read. Software that can understand the words and simple facts in text is already familiar: search engines use facts pulled out of web pages to answer simple questions, for example. Some software can digest scientific information and look for patterns that humans have missed.

But Rambow's system and a range of others are going beyond this, learning to understand the relationships between the characters, how time passes in the text, and whether the characters get what they want.

"Computers can operate at a scale and speed that we can't," says Tom Mitchell at Carnegie Mellon University in Pittsburgh. His group has spent years training computers to digest reams of online content, trying to get a handle on humanity through its text output. He has built a system that can analyse the relationships in a text to figure out which characters are friends and which are enemies.

Snigdha Chaturvedi of the University of Maryland, Baltimore, says that existing natural language processing systems, like Google Now and Siri, are good at answering fact-based questions. "If you type 'Who is president of the United States' it says 'Obama'," she says. "They're very good at fact-based questions, but not very good with opinion."

> **"Software can go beyond facts to understand people's opinions through the things they write"**

Chaturvedi is now developing software that has the potential to go beyond facts to understand people's opinions through the things they write. For instance, future versions could give answers to the subjective question "What did Obama do to win the election?", says Chaturvedi. The software would digest the thousands of online news reports, books and magazine stories about his campaign, finding common elements that appeared in the stories of Obama's victory – perhaps a key person on the campaign, or an important place.

"You could ask similar questions about everyday life," says Chaturvedi. This would bring up a consensus or several options depending on the situation, mined out of humanity's collective written knowledge. Software could be pointed at medical discussion forums, for example, reading everything ever written online to see whether people feel that the drugs and treatments they get are effective.

Computers that can make these kinds of distinctions will be a powerful tool, says Mitchell, since they can read faster and more widely than a human ever could, 24 hours a day. "They could acquire experience that could far surpass what we could ever get in our lifetime," he says. "They'd be a million times better read than you or me."

There are still some issues to overcome, however, such as dealing with text in unusual formats. For example, names are particularly important to the Declassification Engine, and the system relies on the capital letters at the start of names to find them. But the cables come in all capitals, a relic of the Telex system that conveyed them around the planet. Rambow is confident he can get over the hurdle. "I hope that in the next month or two the humming will start," he says. ■

Bush says goodbye to Washington, hello to Texas
MANILA BULLETIN
THE NATION'S LEADING NEWSPAPER
PRESIDENT BARACK OBAMA
hopes and doubts, world awaits Obama

The slow way

LUIS LIWANAG/XINHUA NEWS AGENCY/EYEVINE

A career in science, it's not always what you think

From movie advisor to science festival director, where will your science career take you?

NewScientist | Jobs

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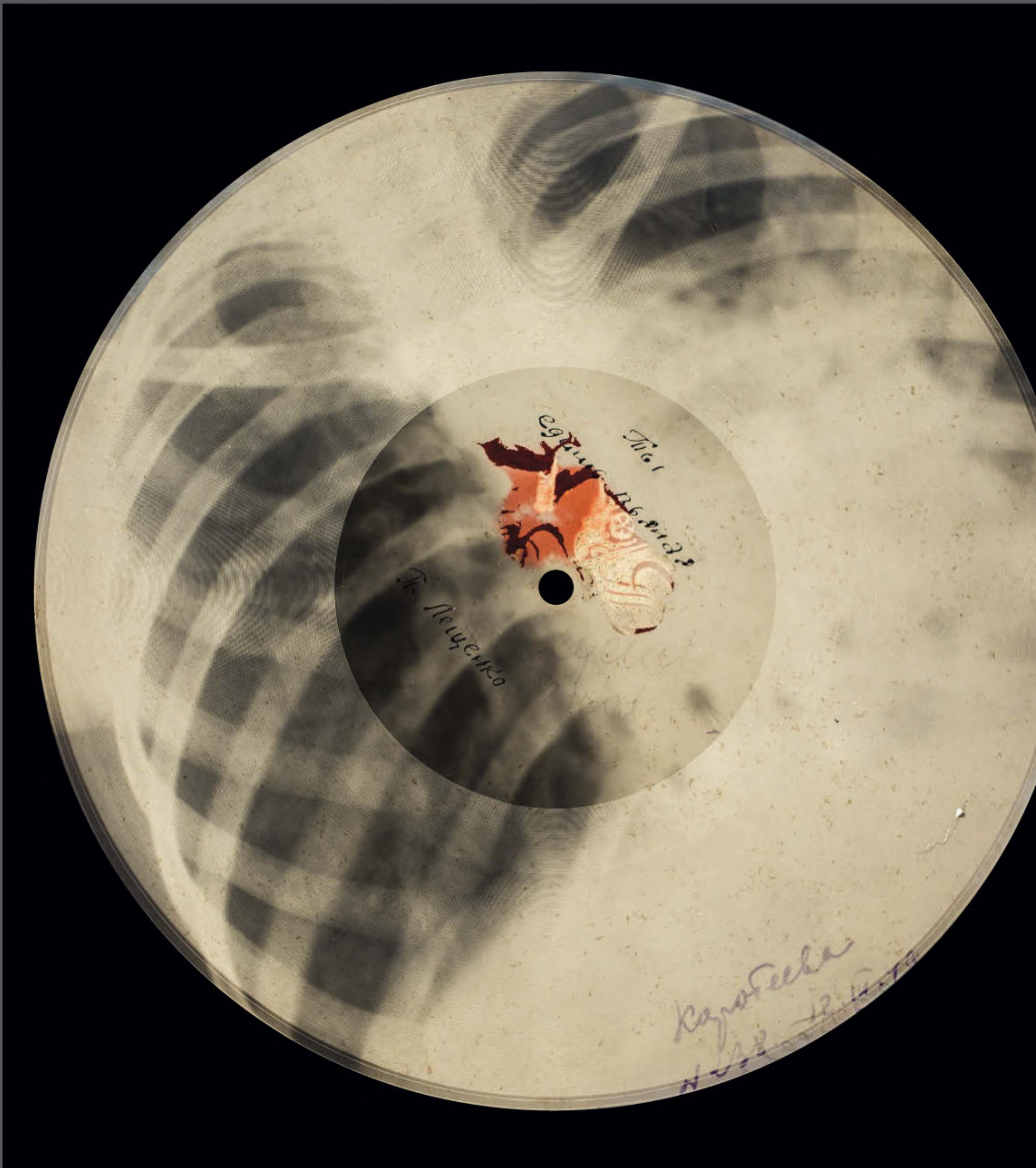
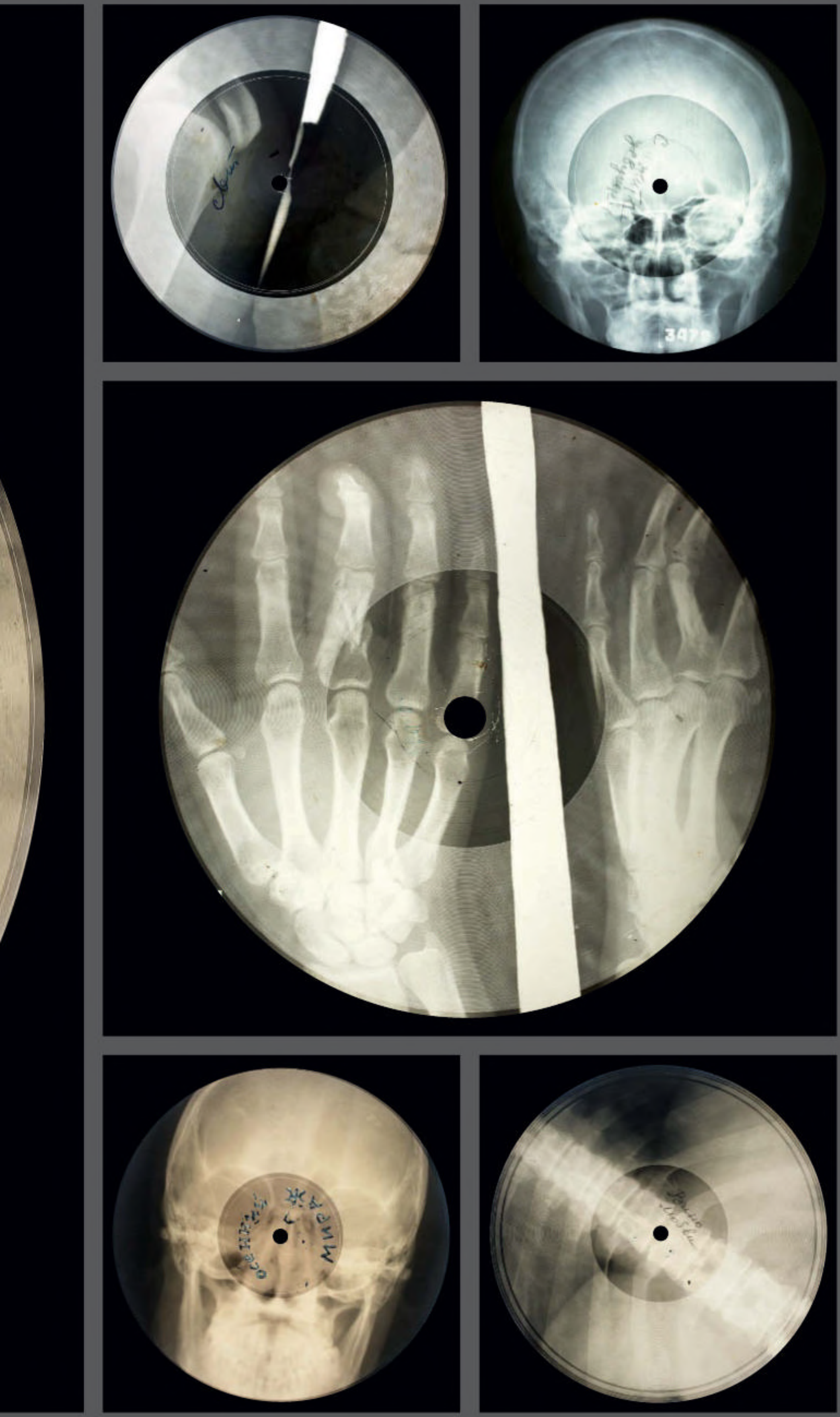

Ты единственная?
П. Лещенко



Bone collectors

YOU could say Soviet-era hipsters had music in their bones. Ghostly bootleg records made from repurposed X-ray plates offer a glimpse into the counterculture movement whose members were prepared to risk imprisonment for rock 'n' roll.

Music was strictly censored in the USSR. Only classical or patriotic tunes were deemed ideologically acceptable – you could be arrested for listening to Western music or even traditional folk tunes. But in the 1950s, a handful of music fans in Leningrad (now St Petersburg) began to defy the state. Before long, an underground cottage industry in home-made records had sprung up.

Unable to get hold of vinyl, the audio dissidents used home-made lathes to press recordings onto X-ray plates salvaged from hospitals. The records were then cut into circles with scissors and the central hole burnt with a cigarette. By the 1960s, *Roentgenizdat* (bone records) could be found on the black market in every Russian city. "They were made by ordinary people," says Stephen Coates, whose book *X-Ray Audio* tells the story of this contraband music. "People ended up in prison for this."

The discs will be exhibited at the The Horse Hospital in London until 19 December. You can listen to some of the recordings at bit.ly/1Ns5ehF.
Clare Wilson

Photographer

Paul Heartfield X-Ray Audio Project
x-rayaudio.squarespace.com

Corrupted code

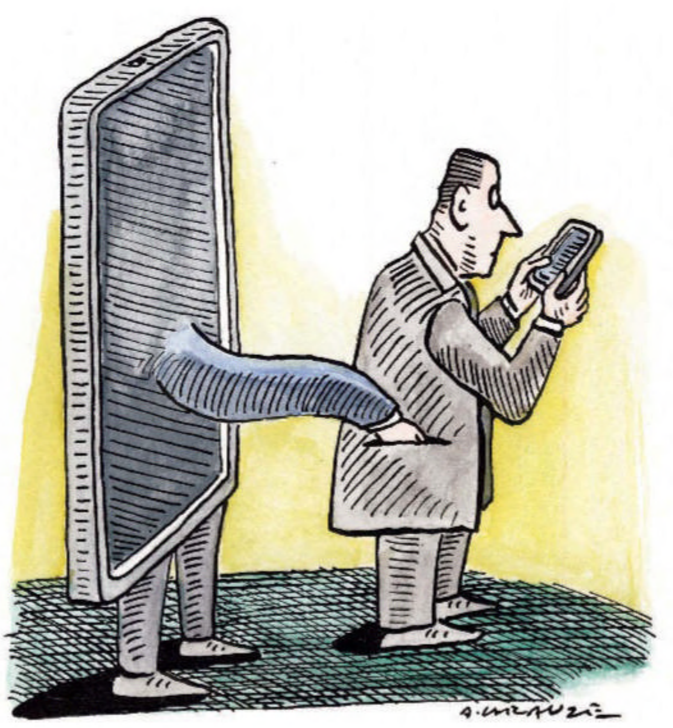
After the VW scandal, how can we trust software that many of our favourite devices rely on, ask **Lee Tien** and **Jeremy Gillula**

AMID the ongoing fallout over the software in some Volkswagen cars that was able to cheat emissions tests, the public may well be pondering a wider question: can we trust the software in the gadgets we use every day? If a car's software can deceive, what might our devices be programmed to do that is not in our interests?

Some TVs and fridges already stand accused of manipulating energy efficiency tests. But software can't just be used to make beating such tests easier. It also makes it easier to lock consumers into proprietary systems and raises suspicions of planned obsolescence.

Whenever devices go online, manufacturers (and others) gain the ability to invade privacy: recall Samsung's TVs with voice recognition that also happened to gather private conversations.

Then there's the vexed issue of security. Insecure software can let attackers open your garage door, hack a baby monitor or remotely control a heart defibrillator. It could even allow them to crash anything from an electric skateboard to a car.



The result is not so much an internet of things as an internet of computers designed by other people in our homes, their software opaque to us and vulnerable to attack. What can be done to win back our trust?

First, firms should not collect data they do not need. Apple's success in processing data on your device, not centrally, proves you don't need to collect every byte to provide a useful service.

Second, companies must issue regular security updates – not take five years, as General Motors did, to fix a vulnerability that could have let attackers control some cars.

Safer sex work

Evidence suggests nations should legalise, not ban, prostitution, says **Clare Wilson**

DO WE help sex workers most by legalising or criminalising what they do? This debate is occupying many Western countries, and it's coming to a head in Scotland.

A proposed bill that would decriminalise prostitution there has just finished its consultation stage. In the UK, selling sex isn't illegal but related acts are, such as soliciting, kerb-crawling and working in a brothel. These would be allowed under the Scottish bill.

In 2012, the Scottish member of parliament behind the idea, Jean Urquhart, favoured a form of criminalisation. Then she went to a debate involving sex workers. What she heard that day and since has led her to "come full circle".

Urquhart's bill is modelled on a 2003 New Zealand law, broadly deemed a success and backed by the World Health Organization.

Some of those responding to her plan are morally opposed to sex work. They invoke God, or can't imagine why anyone would want to be a sex worker unless forced into it. But existing laws address coercion, and modern governments tend not to moralise on consensual adult sex.

Opponents also cite health risks and violence that sex workers can face. Yet a review of 800 studies and reports this year found that criminalisation is linked with more violence, not less.

"A review of 800 studies and reports found that criminalising sex workers is linked with violence"

There are many reasons why: if what you do is illegal, it is harder to work with others or hire guards – that's classed as working in a brothel. If you get attacked you dare not go to the police. And you are less likely to use services that provide free condoms and treat sexually transmitted infections.

Since recent restrictions on Edinburgh saunas used for sex work, there has been no fall in the number of sex workers, but there are reports of unsafe sex, reduced

Third, whenever a device has the potential to cause serious injury, the manufacturer should be required to release source code to regulators. We trust regulators to inspect every other aspect of these devices; why should software be any different?

But the biggest advance would be gaining full control over our devices. This could involve companies releasing source code when they stop supporting a device, and letting users easily install new system software. Then modders could provide new features and security patches.

And who knows? A secondary software market might develop, with innovations the makers of devices never dreamed of. This might sound like a fantasy, but we've seen it realised before – when independent developers put their own software on personal computers, instead of sticking to the system the manufacturer installed.

If we want smart devices to truly flourish, we need manufacturers to give us the same sort of control. Only then will they also regain our trust. ■

Lee Tien is senior staff attorney and **Jeremy Gillula** is staff technologist at the Electronic Frontier Foundation, the digital civil liberties group

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visits to clinics and a small rise in sexually transmitted infections.

Some opponents of legalisation want the "Swedish model", where it is illegal to pay for sex but not to provide it, to avoid penalising sex workers. But a sex worker whose customers get arrested will quickly have no customers at all. So it still forces them to operate in secret, leading to the same problems.

As one sex worker says, the debate tends to revolve around feelings about men who pay for sex and what that says about society. She wants to scream: "What about our safety?" ■

Clare Wilson is a *New Scientist* reporter

ONE MINUTE INTERVIEW

Calling the sisters of autism

The sisters of autistic boys could be key to understanding and helping treat symptoms of the condition, says **Alycia Halladay**

PROFILE
Alycia Halladay is chief science officer at charity the Autism Science Foundation, which has launched the Autism Sisters Project. She holds an adjunct post in the department of pharmacology and toxicology at Rutgers University, New Jersey.

How does autism vary between the sexes?
There are around four times more males diagnosed with autism than females, but the reasons are not fully understood. The current thinking is that females do not develop some of the symptoms possibly because of genetic, hormonal, environmental or epigenetic mechanisms.

Could the difference be down to genes?
In very simplistic terms, a mutated gene linked to autism may be present in boys and girls, but in girls it might not cause the same autistic behaviours. There could be a factor, including genes, that somehow overrides the mutation.

Do environmental influences play a part?
If you think that autism is a combination of genes and environmental factors, then there may be something in females that staves off the effect of environmental factors such as parental age or exposure to chemicals. For example, prenatal hormones like oestrogen could have an influence during development.

Could there be other such mechanisms?
I want to stress that we don't think of this effect as genetic, environmental or developmental factors working in isolation. It is most likely to be a combination. An influence in females may be the way brains in girls develop compared with boys. And boys may project some symptoms of autism more profoundly, whereas girls might cover them up through verbal abilities that develop differently to those of boys.

How will you find these factors?
We have launched the Autism Sisters Project, which will initially look at genetic and epigenetic factors. Large data sets for studying influential effects are lacking, so we want to reach out to families that have a boy with autism and an unaffected sister who have not participated in a study before. We will also add information from earlier studies that include a non-diagnosed sibling. By pooling all this, we hope to get answers.

Are there other examples of conditions that affect females differently?
Club foot is a prime one. Girls have this less often but have more genetic mutations that would cause it, so it is interesting that they don't have as many cases. That's called the Carter effect.

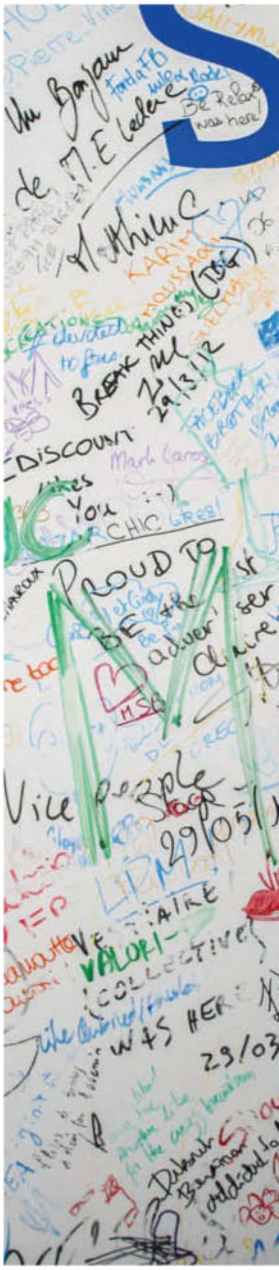
Is the ultimate hope that this will help treat symptoms of autism?
That's the hope. Whatever leads to less autism in females may be something that is effective in intervention. If there is a molecule that can help ameliorate some symptoms, then that really is the long-term goal. But whether or not we find a factor, we will be opening the door to a better understanding of autism just by studying it.

Who can join the study?
We are seeking participants in New Jersey, New York and Connecticut, but we hope to add other sites in the US and include studies from outside the country.

Interview by Jon White

The man behind Facebook's artificial mind

If computers learn common sense, artificial intelligence will really impact our lives, says **Yann LeCun**, Facebook's director of AI



You're trying to make neural-network-based AIs much smarter. What are the big challenges?
The big challenge is unsupervised learning: the ability of machines to acquire common sense by just observing the world. We don't have the algorithms for this yet.

Why should AI researchers be concerned about common sense and unsupervised learning?
Because that's the type of learning that humans and animals mostly do. Nearly all of our learning is unsupervised. We learn about how the world works by observing it and living in it without other people telling us the name of everything. So how do we get machines to learn in an unsupervised way like animals and humans?

Last month, Facebook demonstrated a system that can answer simple questions about what's happening in a picture. Is that trained using explanatory comments made by humans?
It's a combination of human annotation and artificially generated questions and answers. The images already have either lists of objects they contain or descriptions of themselves. From those, we can generate questions and answers about the objects that are in the picture, and then train a system to use the answer when you ask the question.

Are there certain types of questions your AI system struggles with?
Yes. If you ask things that are conceptual, then it's not going to be able to do a good job. It is trained on certain types of questions like those about the presence or absence of objects, or the relationship between them, but there's a lot of things it cannot do. It's not a perfect system.

Is this system something that could be used to automatically caption pictures?
Captioning uses a slightly different method, but it's similar. Of course, this would be useful for people with visual impairment who use Facebook. Or say you're driving and someone sends you a picture, and you don't want to look at your phone. You could ask "What's in the picture?"

Right now, the system just tells you what type of image it is – if it's outdoors or indoors, if there's a sunset, or whatever. It then gives you a list of the things found in it, but it's not like full sentences. It's just a list of words.

So are you saying it doesn't know the relationships between these things?
Right, and so the next generation that we are working on in the lab is more like prose.

What other potential uses do you envisage for neural networks?
In biology and genomics, there is a lot of interesting work. For example, Brendan Frey at the University of Toronto, Canada, has shown that you can train a deep-learning system to emulate the biochemical machinery that reads DNA and produces proteins. With this, you can figure out the relationship between multiple changes in the genome and particular diseases that are not really traceable to a single mutation, but can be an assembly of things. There is going to be a lot of progress in medicine because of this kind of stuff.

Are there problems that can't be solved by deep learning or your image-interpreting systems?
There are things that we cannot do today, but who knows? For example, if you had asked me 10 years ago, "Should we use convolutional nets [a type of artificial neural network] or deep learning for face recognition?", I would have said there's no way it's going to work. And it actually works really well.

PROFILE
Yann LeCun is a professor of computer science at New York University and Facebook's first director of AI science. He is trying to build artificial neural networks that have a sophisticated understanding of images and text: what's in a picture or story, how it all comes together, and what might happen next

Why did you think that neural networks weren't capable of this?
At that time, neural nets were really good at recognising general categories, such as a car or a chair. Those networks are good at extracting the "chair-ness" or the "car-ness" of the object, independently of its specific type or the pose it

DENIS ALLARD/REA

is in. But for things like recognising a species of bird, a breed of dog, or plants or faces, you need fine-grained recognition, where you might have thousands or millions of categories and the differences between them are minute.

I would have thought deep learning was not the best approach for this – that something else would work better. I was wrong. I underestimated the power of my own technique. There's a lot of things that I might think are difficult now but, once we scale up, are going to work.

Facebook recently unveiled a test in which a computer was given a passage from *The Lord of the Rings* and asked to answer questions on it. Is this an example of Facebook's new intelligence test for machines?

It's a follow-up of that work, using the same techniques that underlie it. The group that's working on this has come up with questions that a machine should be able to answer. Here is a story; answer questions about this story. Some of them are just a simple fact. If I say "Ari picks up his phone" and then ask the question, "Where is Ari's phone?", the system should say that it's in Ari's hands.

But what about a whole story where people move around? I can ask, "Are those two people in the same place?", and you have to know what the physical world looks like to be able to answer these questions. To answer questions like "How many people are in the room now?", for example, you have to remember how many people came into this room. To do that, you require reasoning.

Do we need to teach machines common sense before we can get them to predict the future?

No, we can do both at the same time. If we can train a system for prediction, it can essentially infer the structure of the world it's looking at by doing this prediction. An embodiment of this that's cool is this thing called Eyescream. It's a neural net that produces natural-looking images. You can tell it to draw an aeroplane or a church, and for things that it's been trained on, it can generate images that look sort of convincing. That's a piece of the puzzle, to be able to generate images. If you want to predict what happens next in videos, you must first have a model that can generate images.

"I underestimated the power of my own technique. I was wrong"

What kind of things could a model predict?

If you show a video to a system and ask, "What's the next frame in the video going to look like?", it's not that complicated. Moving objects are probably going to keep moving in the same direction. But if you ask what the video will look like a second from now, there are a lot of things that can happen that you just can't predict, so the system will have a hard time making a good prediction.

And what if you're watching a Hitchcock movie and I ask, "15 minutes from now, what is it going to look like in the movie?" You have to figure out who the murderer is. Solving this problem completely will require knowing everything about the world and human nature. That's what is interesting about it.

Five years from now, how will deep learning have changed our lives?

One thing we're exploring is the idea of the personal digital butler. At Facebook, it's called Project M. A digital butler is the long-term sci-fi version of M – like in the movie *Her*. ■

Interview by **Aviva Rutkin**

SPECIAL ISSUE

GET *SMARTER*

Science has given us much to marvel at, from Newton's universal law of gravitation to Darwin's evolution by natural selection. It's wonderful, useful and often beautiful – but sometimes it can feel a little divorced from our everyday realities.

Beyond these great and grand theories, however, there is another canon of knowledge. Grasp these ideas and they can help us lead better, happier and smarter lives. This is the science you need to navigate the world

›

PICTURE CREDIT

NEED TO KNOW

COGNITIVE BIAS

Evolution has made our brains irrational

IT'S Sunday morning and I'm feeling a bit impulsive, so I head to a cafe near my home in London for breakfast. I open the menu and see the following:

MENU

Breakfast

Full English breakfast	£9.95
Smoked salmon & scrambled eggs	£5.95
Waffles with maple syrup	£4.75
Boiled egg and soldiers	£4.00

What would you have picked? I went for the smoked salmon and scrambled eggs. And a surprising number of you would have done the same.

Why so? Understanding the often irrational factors that affect how we make decisions has been a key aim of psychologists over the past few decades – and we're just getting to the stage where we can begin to apply their insights.

That menu first. The reason why many of us would plump for the smoked salmon (besides, perhaps, liking smoked salmon) is to do with something called relativity. That's not Einstein's theory, but rather our tendency to be awful at assessing something's value without being given something to compare it with. As Dan Ariely of Duke University in Durham, North Carolina, puts it in his book *Predictably Irrational*, humans "don't have an internal value meter that tells us how much things are worth".

In this case, the presence of the rather expensive-looking full English breakfast makes the smoked salmon seem like good value. Take the full English off the menu, and more of us will choose one of the two cheaper options. Regardless of whether anyone actually buys the full breakfast, then, its presence means that we're shelling out more than we otherwise would.

BRUNO MANGYOKU

A similar effect, known as anchoring, often kicks in when we're out shopping. Say we have £50 to spend on shoes. We see a pair we like for £100, way above our budget. Then we see a similar pair reduced to £75, and without much thought snap them up. The first price anchors the idea that the second price represents a bargain: we end up thinking we've made a saving when in fact we've spent more than we can afford.

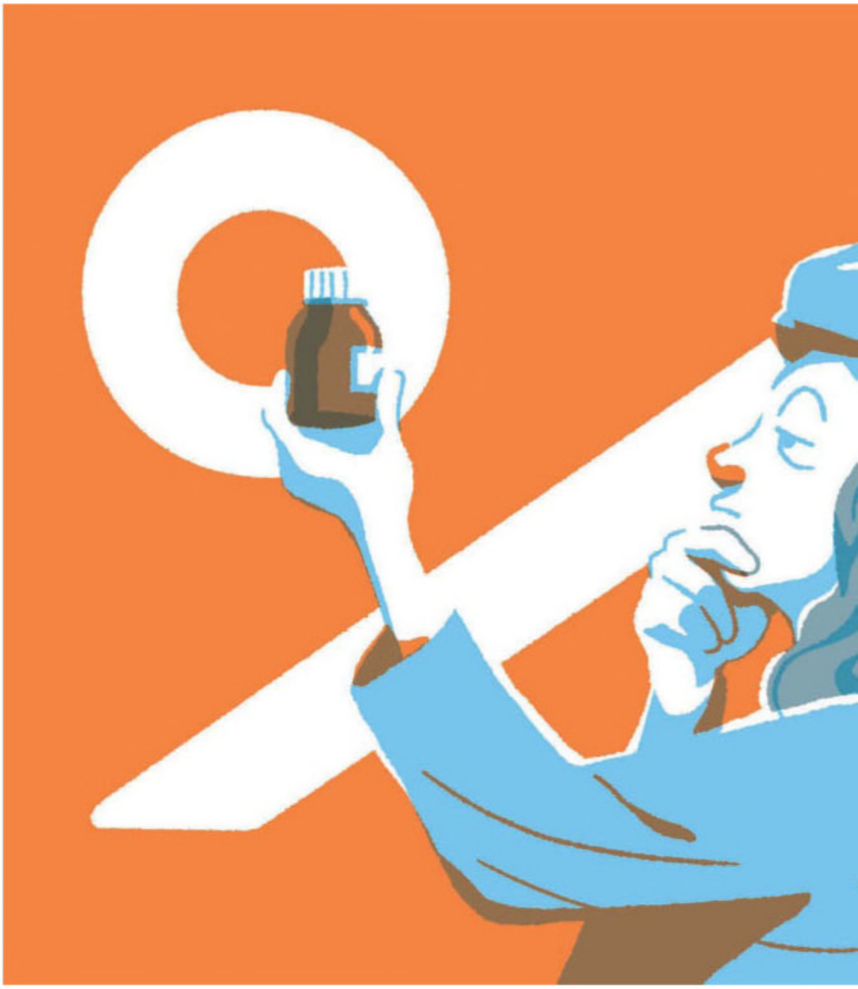
Such foibles persist regardless of the size of a purchase. Another phenomenon called hyperbolic discounting means we tend to overvalue what's available now relative to what we can have later – one reason why many people find it hard to invest in a pension scheme (see "Exponential growth", page 34). Then there's the sunk-cost fallacy, the tendency to stick with something we have already invested in even if all the signs point to this being a bad idea. The classic example is the supersonic jet, Concorde, which never made any money in all the decades it was flying.

There are good reasons why such biases are embedded in our psyches. They have evolved to help us make quick decisions with limited information and difficult decisions with large amounts of hard-to-assess information; to continue foraging in an area that's becoming depleted of fruit or move on to another part of the forest where richer pickings are not necessarily on offer, for example.

But to make more logical, calculated decisions in the complex modern world we need different mental formulae. And there are some simple ways to construct these. A list might include getting yourself or someone else to play devil's advocate to any significant decision; identifying and discounting any sunk costs; and working methodically to eliminate options one by one before coming to a final decision.

> "Awareness of mental biases is good for more than just being smart with our money"

Awareness of our cognitive biases is good for more than simply being smart with our money. It might also help limit the scope for mental blips to cause major disasters, for instance (*New Scientist*, 15 August, p 28). In the wider realm of economics, models that take better account of real humans' irrational decision-making are coming more into vogue to explain events such as the crash of 2008, the better to avoid them in the future. When it comes to improving our futures, it's all in the mind. **Joshua Howgego**



NEED TO KNOW

STATISTICS

Don't believe every number you read

AH YES, statistics. The temptation to start any discussion of this subject with the aphorism popularised by Mark Twain is almost overwhelming. "Lies, damned lies, and..." You know the rest.

We can't afford to be that dismissive. Statistics is the science of drawing informed conclusions from large amounts of data. In a sense, then, it *is* modern science. From trials of the latest wonder drug to the discovery of the Higgs boson, breakthroughs that advance human knowledge are these days seldom made without someone somewhere applying statistical reasoning. And as those bits of knowledge filter down to the rest of us, we are increasingly expected to make decisions – from the political to the medical – on the basis of numbers with that confidence-inspiring suffix "per cent".

Trouble is, few of us do that surefootedly. Sample sizes, false positives and the difference between absolute versus relative numbers are among the factors that affect how we interpret statistics. Often, they are impossible to extract from a bare number.

It's a systemic problem. "There are large numbers of experts – not just laypeople – who have no training in statistical thinking," says Gerd Gigerenzer of the Max Planck Institute for Human Development in Berlin, Germany, and author of *Risk Savvy: How to make good decisions*. "Children are taught the mathematics of certainty: algebra, trigonometry, geometry and the like. That's beautiful but often useless."

For a complex and risky world, he reckons we need a different type of preparation. "We should be taught uncertainty," he says. And that needn't be so difficult. For Gigerenzer, there are a few golden rules we can apply to sharpen our reasoning.

The first is to understand that there is no such thing as certainty, and that looking for it is an illusion. "There are risks everywhere and you need to quantify them," says Gigerenzer.

The second is to look for statistics that encapsulate absolute numbers, not relative ones. Say you read that popping a certain pill will reduce the risk of having a stroke by 50 per cent. This relative number means nothing if you don't know how likely you are to have a stroke in the first place. If that absolute number is 3 in 1000, a 50 per cent reduction will take it down to 2 in 1000 – a puny decrease.

You still might consider the pill worth taking. But wait for Gigerenzer's third rule: always look for the other side of the story. If told about a pill's supposed benefits, for instance, also ask about its potential risks – and make sure both are presented in the same, absolute terms. "I don't want to know whether a drug reduces something by

50 per cent," says Gigerenzer. "I want to know if half take it and half don't, what happens five years later."

In the medical arena, the same reasoning should raise a mental red flag whenever you read of a test being so-and-so per cent accurate – a meaningless figure unless you also know the test's false-positive rate (see diagram, right). Similarly when "survival rates" for a certain condition are quoted or compared: this is a relative measure that can vary considerably depending on how a condition is diagnosed and tested. What you want to know is the mortality rate, an absolute figure that tells you what proportion of the population will die of the condition over a certain period.

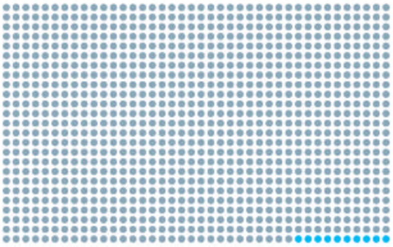
Such rules can help anywhere you see a number with statistical trapping. They have their limits – for example when someone has wilfully cherry-picked their data or otherwise massaged the figures. But they are a good start in sorting out a damned lie from a statistic. **Richard Webb**

Falsely positive?

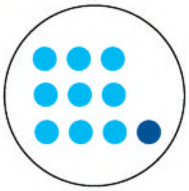
A prenatal test for Down's syndrome can be 90% accurate but also 85% wrong

The risk of having a baby with Down's syndrome varies with age. Assume it's 1%

Of **1000** babies, **10** will have Down's syndrome

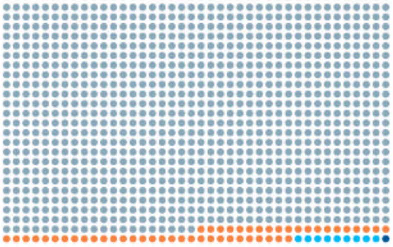


A **90%** accurate test will correctly identify **9** of those babies and miss **1**



But the test has a false positive rate of **5%**

Of the **990** babies who will never get Down's syndrome, about **50** will test positive for it



So in total **59** babies test positive, but only **9** of them actually have Down's syndrome

A positive result thus means the baby has a **15%** chance of having Down's syndrome

NEED TO KNOW

PLACEBO EFFECTS

Harness the power of positive thinking

MY MUM swears that reiki, a technique claimed to channel healing energy through touch, cured her painful frozen shoulder. And my sister promises me a homeopathic remedy will relieve my frequent stomach aches.

Such claims raise eyebrows among those who champion rational thinking. There is often no physiological mechanism by which these and other alternative therapies could work, and they regularly fail to pass the standard tests for efficacy in medicine. But if someone feels better after their chosen remedy, who are we to say it didn't work for them?

At the heart of such questions lies the placebo effect - the way that we tend to feel better just because we believe a medical treatment is going to work, even if the treatment itself is a sham. The power of placebos has been shown in many settings. In one study from 2002, 60 people were even given fake surgery to treat arthritic knees. An elaborate ruse involving doctored footage on a video screen convinced them that they had full surgery, whereas in reality they had only had the skin on their knees cut. Even so, their symptoms improved, and they recovered as well as those who had real surgery. The improvement lasted at least a year.

"We feel better if we believe a treatment will work – even if the treatment is a sham"

"It's hard to believe that sham surgery can produce a long-lasting effect," says Luana Colloca, who studies the placebo effect at the University of Maryland in Baltimore. But it can.

Pain seems particularly susceptible to placebos, but they can also improve the symptoms of other conditions, even asthma and Parkinson's disease. The effects are exceptionally strong in mental-health conditions such as depression and anxiety, says Irving Kirsch of the Beth Israel Deaconess Medical Center in Boston. In 2008, he and his colleagues found that the antidepressant Prozac and placebo were about as effective as each other.

The effect even works if we know about it. In a 2010 study, Kirsch and his colleagues gave an inert pill to people with irritable bowel syndrome. "We told them it was a placebo, but that it might make them feel better," says Kirsch. Even so, the volunteeers ›

saw an improvement in their symptoms.

That doesn't mean alternative remedies like reiki or homeopathy are fine. The placebo effect might make people feel better, but that doesn't mean their underlying condition has improved. Harm might come from not seeking out proven treatments. And of course, any therapy comes at a price – hence the recent squabble in the UK over the public funding of alternative therapies such as homeopathy.

The positive message, though, is that by understanding the placebo effect, we can harness our minds to improve our own health prospects. Simply remaining optimistic when being treated helps, for example – as difficult as that might sometimes seem. So does maintaining a good relationship with your doctor, or surrounding yourself with people you feel comfortable with: studies have shown that hormones such as vasopressin, which are associated with trust, appear to boost the placebo effect.

A pleasant view can make you feel better too; a view of a park is known to improve recuperation compared with a view of a brick wall. If we can use what we are learning about the placebo effect to design medical treatments and clinical environments that are both physically and psychologically effective, we might all end up feeling a lot better. Jessica Hamzelou

ARENDA OOMEN/HOLLANDSE HOOGTE/EYEVINE

Feeling nice after reiki? That'll be the placebo effect

NEED TO KNOW

EXPONENTIAL GROWTH

The mathematical law that can make or break you

"THE greatest shortcoming of the human race is our inability to understand the exponential function." These are the words of the late Albert Bartlett, a physicist at the University of Colorado, Boulder, whose lectures on the subject became a YouTube hit. Arguably, he's right.

Take saving for retirement. "Start early" is the mantra, but it is easy to overlook just how much difference a few years can make. It all comes down to exponential growth – an often abused term that refers to anything that grows in proportion to its current value. It dictates that a forward-thinking 18-year-old can retire as a millionaire at 65 by investing around £250 a month with an average annual return of 7 per cent.

That figure might sound high by today's standards, but it's a rough average of the stock market return since 1960. The surprise is that when our saver reaches 55, the savings will amount to a little under £500,000. Thanks to the power of compound interest, however – exponential growth by another name – it will double to £1 million just 10 years later. Wait

NEED TO KNOW

PROBABILITY

Coincidences are more common than you think

IMAGINE you receive an envelope addressed in an unfamiliar hand. Enclosed are predictions for this weekend's football matches and an offer to invest in the sender's foolproof betting syndicate. What tosh, you think, shoving it in the recycling bin.

But come the weekend, you notice that those tips turned out to be correct. And then comes the really strange bit. The next week, an identical letter arrives with predictions for that weekend's games – and they turn out to be accurate too.

At this point, you send off your cash, convinced that whoever this person is possesses some genuine insight. (Either that, or you go to the police to report that you've uncovered the biggest match-fixing scandal yet.)

Or if you're familiar with the law of large numbers, you might be tempted to bide your time. This law, a facet of the perennially bamboozling subject of probability, states that, given a large enough sample size, any outrageously improbable thing is eventually bound to occur. If our sly soothsayer simply sent letters systematically to enough different people, each with a different set of scores, then at least one recipient is likely to get accurate predictions enough times in a row to make them bite. And even if just a few people hand over their money, it probably makes the scam worthwhile.

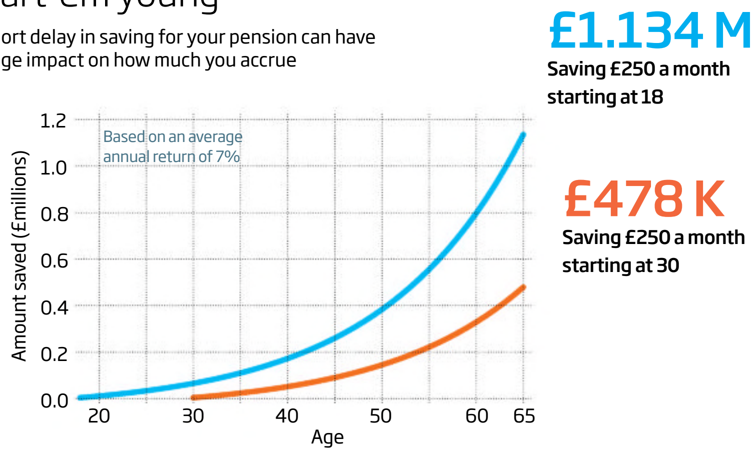
This sort of trick works so well because the existence of these hundreds of disappointed punters never occurs to us. "It's very difficult to count all the times something could have happened and didn't," says David Spiegelhalter, a statistician at the University of Cambridge.

Another way this plays out is in the birthday paradox. You're at a party with 23 guests and are surprised and delighted to find another guest shares your birthday – what a coincidence! In fact, a little calculation shows you the odds of this happening are better than 50:50. Again, the crucial point is the number of possibilities. One person in the room can share a birthday with any of the 22 others, and there are 365 days on offer in a standard year for this to happen. A second person can also share a birthday with any of the others, and so on. Continue adding up the possibilities for each person, and you end up with enough to make a shared birthday more likely than not.

We have this blind spot for large numbers for good reason. Being hypersensitive to "coincidences" was handy in our evolutionary past. "By following coincidences we make important discoveries," says Tom Griffiths, a cognitive scientist at the University of California, Berkeley. We first had to realise that the sun rises every day, and search for an underlying cause, before we could (eventually) conclude that Earth rotates. Equally the recurrence of stomach pains and worse taught us to stay away from certain berries.

Start 'em young

A short delay in saving for your pension can have a huge impact on how much you accrue



until you're 30 to start saving that £250 and you'll only reach about half as much (see diagram, above right). Starting at 30, you'd actually need to save more than £600 a month to make it to £1 million by 65.

Exponential growth's stealth factor is nicely illustrated by the story of the man who invented chaturanga, an Indian precursor to chess. He presented his king with a beautifully laid out board divided into 64 squares and when asked to name his reward, requested a grain of wheat to be placed on the first square, two on the next, four on the third, and so on. It sounded a modest reward, but had the king obliged across the board, he would have given away more than 18 billion billion grains. Fail to understand exponential growth, and our debts can rapidly spiral out of control too. This is an engine for creation and destruction wrapped up in deceptively simple maths.

In reference to the chaturanga legend, US futurist Ray Kurzweil refers to the sudden changes that spring from exponential growth as the "second half of the chessboard". The number of transistors that can fit on a electronic chip provides an example. Over the past few decades, it has roughly doubled every 18 months, a phenomenon known as Moore's law. The accelerating effect of exponential growth explains why we spent 25 years with bulky desktop computers before rapidly switching over to sleek smartphones. Kurzweil is famed for believing that this sort of technological growth will lead to an event called the singularity, when computers will become powerful and smart enough to improve themselves and outpace us all.

The spread of viruses often works in a similar way: one ill person infects a few others, who in turn each infect a few more, until we've got an epidemic on our hands. Immunisation acts as the limiting factor, which is why the world scrambled to treat last year's Ebola outbreak, which at one point saw the number of known cases doubling every few weeks.

When it comes to exponential growth, you can't trust your short-term instincts. Whether it's finance or technology, the largest changes won't happen for some time. But when they do, your whole world can be turned upside down in an instant. **Jacob Aron**

"We just happen to live in a world where most of the relevant causal relationships have already been discovered," says Griffiths. The result is we see patterns where none exist. Our problem with coincidences today, then, is a relic from a simpler world, like cognitive bias (see page 31).

Looking past what our gut tells us, at the often hard truths revealed by probability, calculations can also help us in balancing the risks we all face in our daily lives, from not taking an umbrella to not taking out an insurance policy. That probability is so useful is no coincidence. **Gilead Amit**

"Given a large enough sample, any improbable thing is eventually bound to occur"

GAME THEORY

The science of strategic thinking

IN THE film *A Beautiful Mind,* John Nash and his buddies, all of them graduate students in mathematics at Princeton University, are sitting in a smoky bar when a group of women walk in. As the men tease each other about their chances, Nash is struck with inspiration. Is there a logical, mathematical way of working out the best strategy for each man getting a date? Next thing you know he's shambling out of the bar, and spends the night furiously scribbling unfathomable-looking equations.

It sounds a little crass, and the episode probably never happened in reality. But in a ham-fisted, Hollywood sort of way, it does hint at how game theory, the branch of mathematics Nash helped to make famous, can apply to our everyday lives.

In fact, we use it all the time without even realising. "Every time you think about what you should do in terms of what someone else will do in response, you're doing rudimentary game theory," says Kevin Zollman of Carnegie Mellon University in Pittsburgh, Pennsylvania.

The trouble is, we are novices. When we need to think through situations several steps ahead or when they involve more than just a few people, we start to make mistakes. But delve into the theory just a little – there's no need to be a maths whizz – and you can harness some of the insights to make smarter moves in your own life.

Lesson one is that there are different sorts of games. Broadly speaking, there are zero-sum games, in which one player gains what the other loses, and variable-sum games, in which players have both common and opposed interests.

An example of a zero-sum game would be chess or poker. When you win, your opponent automatically loses and vice-versa. These sorts of situations don't crop up much in everyday life. Variable-sum games are more common and more complex. They are exemplified by what's known as the prisoner's dilemma, a scenario in which the punishment you receive for a crime depends on both your plea and that of an accomplice. You don't know how your accomplice will behave, but game theory organises the possible outcomes into a pay-off matrix that allows you to think through the various possible outcomes (see "Decisions in the frame", below).

It turns out, perhaps counter-intuitively, that your best option for both you and your accomplice is to confess. This decision is what's known as a Nash equilibrium because neither party can benefit from making a different choice while the other party's choice stays the same.

> "There is another way to win at chicken: throw the steering wheel out of the window"

Nash died in May, but his contribution to game theory, including the equilibrium idea, helped him win a share of the 1994 Nobel prize in economics. Lessons from the discipline have been applied all over the place, from politics and diplomacy to economics and business. It helped the US formulate its nuclear deterrent strategy during the cold war, for instance. Today, broadcasters use it to jostle for the rights to air top-level sports fixtures.

But individuals can harness insights from game theory, too. One example is understanding the power of "credible commitment", says Rakesh Vohra, an economist at the University of Pennsylvania in Philadelphia. This concept is best described by a game of chicken. Think of two cars accelerating towards each other; the loser is the one who swerves. Here, the Nash equilibria are the two situations in which one player swerves and not the other.

But a game theory analysis shows there is another possible way out. One of the drivers can force an outcome by changing the rules of the game – for example by removing the steering wheel and throwing it out of the window. Then the other driver must swerve to avoid destruction. "You're making your opponent recognise that you have no choice but to take a particular action, which then forces them to do what you want them to do," says Vohra. "Paradoxically, limiting your options can sometimes make you better off."

The same principle can be applied to buying rather than crashing a car. Do your research on prices and make a take-it-or-leave-it offer. "By committing yourself, you force the seller to make a choice: either sell at that price or make no sale at all," says Vohra. This reasoning applies to any situation in which two competing parties have to negotiate a price, including agreeing a salary for a new job, for instance.

Be warned, however: even the greatest game theorists won't always get it right. The problem is that game theory assumes we act rationally all the time – and we don't (see "Cognitive bias", page 31). Even the experts will sometimes be thrown off by the quirks of human behaviour. **Daniel Cossins**

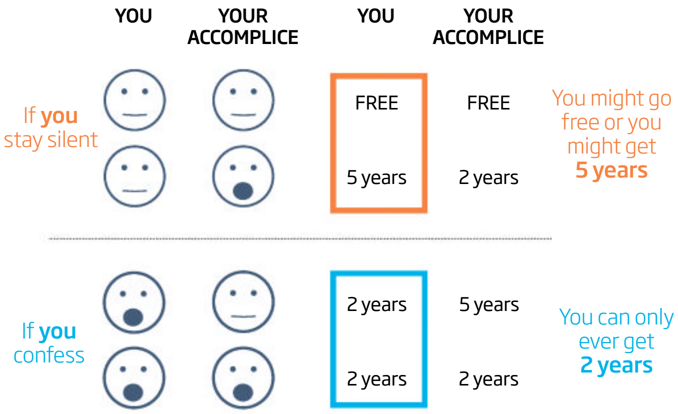
Decisions in the frame

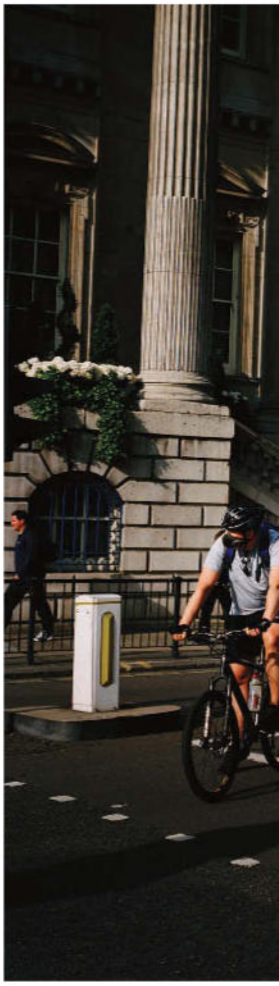
Game theory provides us with a framework to make decisions when we have incomplete information – such as in the famous prisoner's dilemma

You and an accomplice are being held separately for a crime.
The maximum penalty is 5 years – or 2 if you confess

The police can only prosecute if one of you confesses – if neither does, you walk free

Should you stay silent or should you confess?





TRENT PARKE/MAGNUM PHOTOS

NEED TO KNOW

HIDDEN ENERGY

Say goodbye to greenwash

SOMETIMES you want to make a decision that helps the planet. Maybe you're selecting an electricity supplier, choosing whether to sign a petition against wind farms or wondering whether to install solar panels. The right option might seem obvious: who could argue with the green credentials of a solar panel, for instance? But such decisions are often harder than you think.

Often the problem comes down to hidden energy. Energy is most obvious when it is kinetic, producing a visible effect such as when you kick a ball or wrench open a door. But energy is also needed to make things, and is locked up, or "embodied", in all sorts of manufactured matter, from a metal pipe to a slice of pizza.

Take buying a car – a big purchasing decision that could have a more significant impact on your carbon footprint than most. Say you've decided to swap your old petrol-powered banger for a new, fuel-efficient version. If your current car was manufactured a decade ago, it might typically pump out about 1.8 tonnes of carbon dioxide a year, if you drive an average sort of distance of 12,000 kilometres. If you were to buy the most fuel-efficient model you can find on garage forecourts today, and drive a similar sort of distance, you'd emit about 1 tonne annually, according to company-declared emissions at least.

That seems like a worthwhile saving, but crucially we've yet to consider the energy embodied in the car. It takes energy to run the machines that built it and to produce the materials that form it, and this also generates CO_2. According to manufacturers' figures, the process of making a car typically takes between 600 and 800 kilograms of CO_2. Factor in making the steel for the body itself, and you can add in another tonne of emissions. Add in the carbon footprint of the aluminium components – which require five times more energy to smelt than steel – plus upholstery, glass, rubber and electronics, and your new car clocks in at around 6 tonnes of CO_2, according to the UK's Carbon Trust. You'll have to run it for at least eight years to recoup its carbon cost.

Faced with such figures, you might consider going the whole hog and buying an electric car. Here the same sorts of embodied emissions will be involved as with the petrol car, but at least there are no emissions from the exhaust, right? Sure – but if, when you plug the car into the mains, it is sucking power from a carbon-belching coal-fired power station, it has merely shifted its emissions elsewhere.

> "They might seem easy, but few green choices are as straightforward as they first appear"

So beware: manufacturers will often try to play on your sense of environmental responsibility, but few green choices are as straightforward as they first seem. With a solar panel, what is the emissions cost of making the slab of highly purified silicon it's probably made of? Or of the huge magnets that help harness the energy from a wind turbine?

Asking such probing questions can give you a whole new perspective on a range of decisions, for example what you eat. Say you live in the UK, and you have a choice of a locally grown tomato or one grown in Spain. It's common to think the green option is to limit the food miles travelled and go for the local produce. But the embodied emissions associated with heating the hothouse in which the UK tomato was grown might easily – depending on how the Spanish tomato was freighted in, by air or by lorry – trump the embodied emissions associated with transport.

Such considerations rarely make our decisions easier. If you opted to ditch the new car entirely and cycle to work instead, for instance, what is the carbon cost of shipping in all those extra veggies to power your leg muscles? But then no one said saving the planet was easy. **Fred Pearce**

INTERNET ARCHITECTURE

Where your data goes determines how much you can hide

SNAP. You press the shutter icon on your phone and capture a photo of your baby daughter. With a couple of swipes, you attach it to an email in your Gmail app and fire it off to your mother-in-law.

As personal data goes, it doesn't get much more innocuous. But the truth is that spraying around any private information is risky. You might think that's overblown. As long as you have nothing to hide, you have nothing to worry about.

It's not that simple. Just look at this summer's hack that exposed the data from Ashley Madison, a site catering for people looking for an affair, and imagine if the same happened with all your emails stored by Google, or your photos on Facebook. Even if you've done nothing illegal or immoral, faced with a database of every photograph and comment you've ever shared privately, friendships and business deals could dissolve the world over.

And there are plenty of vulnerabilities. The material displayed on the web is stored, often in central server farms. Whenever you upload text or pictures, they are ferried to these farms by cables. Although there are safeguards, data can in theory be hacked, stolen or altered at many points along the way.

Let's return to that photo, and imagine that once your mother-in-law receives your email, she immediately uploads the baby pic to Facebook. The likelihood is that even such an everyday occurrence will send information pinging on unexpected routes around the world, often leading it to be stored in places with unfamiliar privacy laws (see "Around the world in 80 microseconds", right).

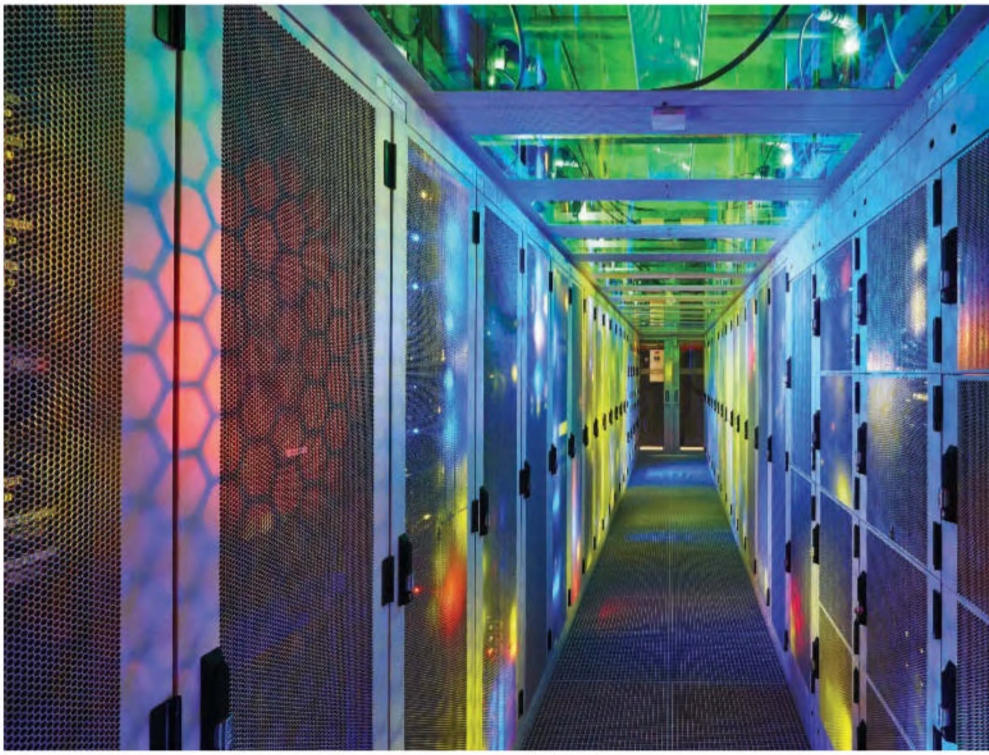
Bear in mind, too, that companies such as Google and Facebook will often store many copies of your data. Andreas Olah, who researches server architectures at market analysts IDC, says Facebook copies your data into formats readable by all sorts of devices and creates backup copies. If your mother-in-law had recently been on holiday to the US, Facebook would probably have sent the photo to a US data centre too, just so that she wouldn't have wait for it to load were she to visit again.

In short, one simple share can create reams of potentially hackable data. This state of affairs demands caution from all of us, says Judith Lewis, a consultant based in London who previously worked on email security. "Just pretend you have a stalker who sees everything."

Studies show that people with more complete mental models of the physical internet also have a fuller understanding of privacy risks. Unfortunately, the same research found that this understanding leads to "security fatigue" – we get bored with worrying.

What can we do with this knowledge, anyway? A common refrain is that you should encrypt everything. Encryption has traditionally been hard to learn and required enthusiastic adoption not just from you, but everyone you communicate with. "If we want privacy to be protected, the only way to do it is collectively," says Alessandro Acquisti, a cyberprivacy researcher at Carnegie Mellon University in Pittsburgh, Pennsylvania.

Encrypted web communication protocols such as the https system commonly used for internet shopping and banking, and those that underlie some popular messaging apps, have made that easier. But a better solution might be to include protection in the core design of devices and online services. The Blackphone, released in



MARK HORN/GETTY

Around the world in 80 microseconds

You use Google's email service Gmail to send a cute baby pic to your mother-in-law a few miles away, who then posts it to Facebook. That data will be stored on server farms like the one pictured above – but where? Starting from *New Scientist*'s London, Boston and Sydney offices, it goes something like this

FROM LONDON...

The Gmail pings around London then speeds under the sea to be stored in Dublin, Ireland, where Google has a huge data centre. When your mother-in-law posts the picture, it lands at Facebook's new European data centre in Lulea, Sweden – a country that gives itself permission to investigate any data crossing its borders. It is also backed up at Facebook original data centre at Prineville, Oregon.

FROM BOSTON...

After ping-ponging across the US – but never leaving it – the photo lands at Lenoir, North Carolina, the closest of Google's seven US data centres. It is also stored at Prineville, and backed up at a couple of other locations. Gmail encrypts data, so the average hacker is probably not a problem on this circuitous route; the US National Security Agency, which maintains "backdoors" to US technology company servers, perhaps more so.

FROM SYDNEY...
Neither Google nor Facebook maintain data centres in Australia. The email is stored in Singapore or Taiwan; the western US is again the destination of the Facebook photo. Many nations don't like data straying outside the protection of their own privacy laws. A recent European court ruling might mean US firms will no longer be able whisk data across the Atlantic – perhaps paving the way for countries to insist on having data centres on their turf.

September and powered with Google's Android software, allows you to use any app you like but feeds it blank fields instead of the data it expects.

The Blackphone will set you back $799, and Google still gets your data, even if third parties don't. Plus, it doesn't allay the worry that others might not take care with your data. "No matter how securely you share something, the recipient can still be stupid with it," says Lewis. A basic understanding of how the internet works should give us pause for thought in how much we share. **Sally Adee**

TRACE YOUR OWN DATA

Data you produce online will take various routes. Follow these steps to start tracking

1. Open the terminal application on your computer
   Mac: Applications > Terminal
   Windows: All programs > Accessories > Command prompt
2. Type "tracert yyy.com" and hit enter where yyy.com is the website you are visiting
3. Watch as your route through the internet is traced

The long numbers are the IP addresses of the computers that are routing your data. The strings of letters are the machines' hostnames, indicating which company is running the computer. Buried in the hostname are airport codes, indicating the cities each machine is in.

NEED TO KNOW

EPIGENETICS

Your lifestyle can change your genes

DID you hear the one about how the giraffe got its neck? Aeons ago there was an animal that walked along a dusty path to a watering hole every morning. Halfway, she would spot a patch of trees with the tastiest, most succulent leaves on the savannah. Stretch as she might, she couldn't quite reach them. Then one day the stretching paid off, and she suddenly had a mouthful of juicy fronds. Years passed, and the giraffe had babies. Over the generations they became spindlier and spindlier, reaching ever higher into the treetops.

It could be one of Rudyard Kipling's *Just So Stories,* and you can see its charm: keep studying, training and eating healthily, and you can change yourself for the better. Not only that, but your efforts will endure and future generations will benefit, too.

It's just a shame that scientists from Darwin onwards have said that this picture is flat-out wrong. Random mutations in DNA, corralled by the forces of natural selection, fuel evolutionary change.

There's no change in that basic picture, but some recent research suggests that elements of our giraffe story might not be so wide of the mark after all. Far from being a rigid instruction manual, our DNA is flexible and responsive – and we might be able to change much more than we thought.

Almost all your cells hold the same 20,000 or so genes, but each type of cell uses a unique suite of them. Genes have to be turned on and off at the right time in the right place. The mechanisms by which this happens are referred to as "epigenetic", acting over and above the genetic code.

Epigenetic information is written into our genes through a series of biological marks that don't affect the underlying DNA sequence. A dazzling array of chemical tags can be stuck onto the proteins that package DNA, or even DNA itself, masking certain parts of our genomes from the cell's gene-reading machinery or making them more enticing. Crucially, our cells can rub out and rewrite these epigenetic marks to turn genes on or off.

Munching on broccoli, supping on green tea and exercising are just a few activities that have been linked to changing our epigenetic marks for the better. And it works the other way too: some researchers lay the blame for ailments ranging from allergies to cancer to Alzheimer's disease at the door of dodgy epigenetic switches.

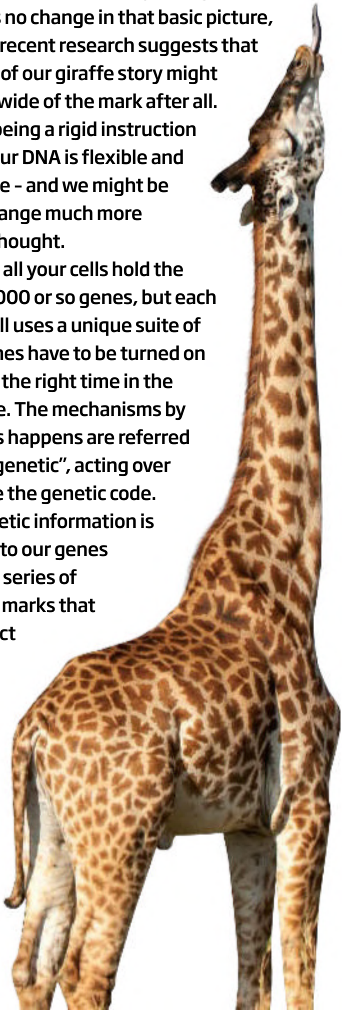
Things start to get really interesting when we ask whether epigenetic changes can be passed down the generations. If true, it would mean that the behaviour of a parent could affect how their babies, and even those of their children, develop, and even influence the diseases they might succumb to later in life.

For this to happen, epigenetic marks would need to be written into the DNA of eggs or sperm and preserved in the resulting offspring. There are mechanisms to wipe the epigenetic slate clean between generations, but some studies hint that this doesn't always work perfectly.

And there are some intriguing examples of the experiences of past generations seeming to affect subsequent ones. In a famous case known as the Dutch Hunger Winter, the children of women who conceived during the famine caused by the second world war were born smaller than average – as were their grandchildren, even though they were living at a time of post-war plenty.

For now, solid examples of this happening in humans are rare, but the evidence is growing. It's certainly one to keep your eye on: if your gym habit, penchant for pizza or caffeine addiction is going to have cascading effects on your unborn children, you ought to know about it.

Kat Arney is the author of the forthcoming *Herding Hemingway's Cats: Understanding How Our Genes Work*



DENIS-HUOT/NATUREPL.COM

AURORA PHOTOS/PLAINPICTURE

Lost beneath the ice

At last we're glimpsing the pulsating landscape under Antarctica's frozen blanket, says **Anil Ananthaswamy**

IT TOOK three weeks of crossing frozen terrain to reach the lake, and five days to punch a hole through its icy lid. When they finally broke through to the water below, the excitement was palpable. Hands grabbed the gooey mud pulled up through the hole. For this was no ordinary ice-fishing expedition: Slawek Tulaczyk and his team had drilled through 800 metres of ice into Antarctica's Lake Whillans.

The team's efforts – battling through 14-hour shifts in some of the harshest conditions on Earth – are part of a massive endeavour to uncover the continent's hidden secrets. Over a century ago, explorers trudged across its white blanket in pursuit of world records, aware only of the snow, ice and treacherous weather. But in the last few decades a different kind of explorer has started to peer beneath the ice, to discover what Jill Mikucki at the University of Tennessee in Knoxville describes as a sub-ice water-world. Their labour has revealed a pulsating continent with lakes, rivers, volcanoes, even life: hardly the frozen wasteland of popular imagination.

In a way, the adventure began in 1957, when a ship carrying members of the third Soviet Antarctic expedition arrived at the East Antarctic ice sheet. Their aim was to establish a base near the Pole of Inaccessibility, the furthest point on the continent from the Southern Ocean. Thirty-two men struck out from the coast with the equipment that was left after a storm broke up the ice around their ship while they were unloading – sinking sledges and a tractor but no men.

At regular intervals along the way, they set off small explosives and recorded the echo of seismic waves as they travelled through the ice and bounced off whatever lay beneath. Near the centre of East Antarctica, the explorers found a region of anomalously thin ice. They had stumbled across a massive mountain range beneath, its peaks reaching up towards their feet (see picture, page 43). Almost 3000 metres high, the Gamburtsev mountain range has an Alpine topography, replete with rugged peaks and hanging valleys, yet it is completely hidden from view.

The ice above is anywhere from a few hundred metres to 3.2 kilometres thick.

Then, during the late 1960s and early 1970s, planes equipped with ice-penetrating radar revealed bodies of water locked between the ice and the bedrock: lakes hundreds, sometimes thousands of metres beneath, and still liquid thanks to the immense pressure of the ice above and geothermal heat from below. These were the days before GPS and its Russian equivalent GLONASS, and pilots had to keep the Soviet Vostok research station in their sights or risk getting lost over the vast, white, featureless expanse. So it was pure luck that beneath the station sat the continent's biggest lake: Lake Vostok, seventh largest in the world by volume, fourth deepest and 3.7 kilometres under the ice.

Vostok – like Antarctica's other large lakes – sits in a depression in the bedrock and is "inactive": it fills and drains very slowly. But in recent years, teams studying other subglacial lakes have discovered a dynamic system of streams and even rivers that interconnects some of them.

Duncan Wingham of University College London and his team were the first to spot the massive movement of water beneath the ice. In 2006, they showed how parts of the East Antarctic ice shelf rose and fell, as if the ice were breathing. When the ice sank in one location, a similarly abrupt rise was seen several hundred kilometres away. They concluded that water was flowing from one set of buried lakes to another. "That was quite a revelation," says Hugh Corr of the British Antarctic Survey (BAS).

At the last count, polar researchers have identified about 400 subglacial lakes in Antarctica (see map, page 42). The discovery has turned the image of a massive ice sheet grinding against the bedrock on its head. Rather, there is an entire hydrological system between the ice and rock. "Just how much water there is underneath has been a surprise," says Corr.

"The temperature under the ice was extremely hot – Yellowstone hot"

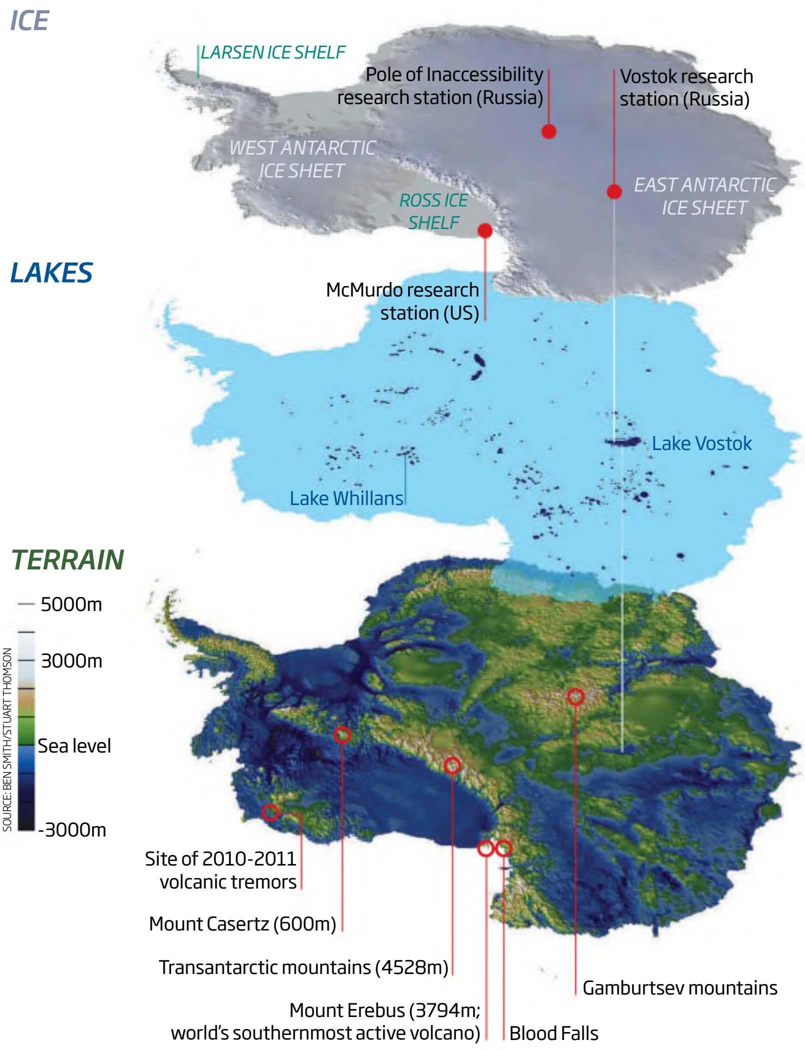
There's fire down there, too. During the 2004-05 Antarctic summer, a joint US-UK team carried out an airborne survey to take radar, magnetometer and gravity measurements near Pine Island glacier in West Antarctica. They found something hundreds of metres beneath the ice surface that strongly reflected their radar signal. Corr and David Vaughan, also at BAS, analysed the findings and concluded that the reflections were coming off a layer of ash and rocks, the remnants of a massive volcanic eruption.

The volcano, known as Mount Casertz, erupted about 2000 years ago, punching its way through the ice to spread debris over 26,000 square kilometres. The explosion would have been on the scale of the 1980 blow-up of Mount St Helens in the US. Even today, the ice over Mount Casertz is depressed, suggesting heightened geothermal activity underneath. And in 2010 and 2011, seismometers picked up the rumblings of another active volcano in West Antarctica.

It was against this backdrop of fire and ice that Tulaczyk, of the University of California in Santa Cruz, set out for Lake Whillans in West Antarctica. In December 2012, an advance party of tractors – each dragging a chain of shipping containers mounted on sledges – had to cover the 800 kilometres separating the McMurdo research station from the lake. The containers held nearly 500 tonnes of ›

Hidden landscapes

Beneath Antarctica's ice cap are huge mountains, active volcanoes, hundreds of lakes, rivers and even life


ICE
LARSEN ICE SHELF
Pole of Inaccessibility research station (Russia)
Vostok research station (Russia)
WEST ANTARCTIC ICE SHEET
ROSS ICE SHELF
EAST ANTARCTIC ICE SHEET
LAKES
McMurdo research station (US)
Lake Vostok
Lake Whillans
TERRAIN
5000m
3000m
Sea level
-3000m
Site of 2010-2011 volcanic tremors
Mount Casertz (600m)
Transantarctic mountains (4528m)
Mount Erebus (3794m; world's southernmost active volcano)
Blood Falls
Gamburtsev mountains

SOURCE: BEN SMITH/STUART THOMSON

equipment. Designed to be stacked on ships, not pulled across undulating, wind-hardened ice and snow, they didn't travel well. The crew had to keep welding fractured metal, sometimes cutting parts from one container to patch up another.

By the time the convoy reached the remote site and Tulaczyk and 60 more scientists had flown in from McMurdo, it was mid-January. They had until the end of the month before temperatures would begin to fall. In that time they had to drill through 800 metres of ice to Lake Whillans, drop their instruments through the hole one by one, take measurements, gather samples, then pack everything up and head home.

Tulaczyk remembers the day they finally broke through and dredged up mud from the lake bed. "People were grabbing the stuff as a souvenir," he says. "After spending weeks and weeks surrounded by just snow, to have this very tactile, physical evidence that there is something else [besides] ice underneath our feet… It was so amazing for them."

One of the instruments dropped down the hole was a sensor to take the lake bed's temperature. Until then, there had been only indirect hints that Antarctica's underbelly was warm. "The measurement came out to be extremely hot – Yellowstone hot," says Tulaczyk. Similar measurements have been taken at some 35,000 sites around the planet. Only 100 or so are hotter than the Whillans lake bed.

We don't yet know why West Antarctica is so hot and volcanic. It could be that the crust is thinning there. As an analogy, Tulaczyk points to the area between the Sierra Nevada mountains in the western US and Salt Lake City in Utah: over time, the two have moved apart, stretching the Earth's lithosphere and producing geothermal and volcanic activity.

Or, paradoxically, the heat could be generated by the ice. The West Antarctic ice sheet has grown and shrunk many times over the past few million years. When the ice is thicker, it depresses the crust, which rebounds when the ice melts. As the crust bobs up and down, so does the viscous mantle 100 kilometres lower down. This constant massaging of the mantle can release heat.

Life ahoy!

Whatever its source, geothermal heat means liquid water – and that could, in turn, mean life. In the McMurdo Dry Valleys, bright red brine flows from cracks in the Taylor glacier on to the frozen surface of Lake Bonney (pictured above). The striking colour of Blood Falls, as the site is known, is the result of iron particles that oxidise in the sunlight. Inside the brine, Mikucki and colleagues have found evidence of "chemoautotrophic" bacteria that live in complete darkness – presumably beneath the Taylor glacier – by chemically leaching energy from the bedrock and producing iron as a by-product. They don't rely on energy from the sun, not even in the indirect way that, say, fish at the bottom of the ocean do when they eat dead material that falls from the surface.

The team now want to find where the bacteria come from. Blood Falls is a salty waterfall, and salty water conducts electricity better than freshwater. So earlier this year, Mikucki and her team went out to the area with instruments that can remotely measure electrical conductivity beneath the ice. They found large pockets of high conductivity

Blood Falls offers clues to how life survives beneath the ice

USAP

beneath the Taylor glacier. The researchers believe the sediments there are saturated with brine and could host the microbial ecosystems that flow out at Blood Falls.

Although soggy sediments that can support microbial life are definitely prized findings, the treasured goal for Antarctic researchers is to find life in liquid subglacial lakes. Over the past decade Russian scientists have been drilling down to Lake Vostok. The first time they broke through to it, in February 2012, the samples they brought back up to the surface were badly contaminated with the drilling fluid they used to keep the borehole open. After colleagues in Grenoble, France, cleaned them to remove any trace of contaminants, the Russians found no conclusive signs of microbial life.

When they broke through to the lake a second time, in January this year, special care was taken to prevent contamination. But with their current drilling equipment, it's hard to avoid contamination entirely. Any search for life under these conditions is bound to be inconclusive.

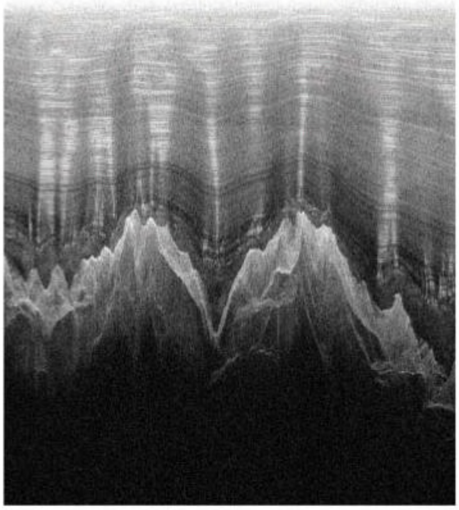
"We need clean water samples to make conclusions. We dream about it," says Irina Lekhina of the Arctic and Antarctic Research Institute in St Petersburg, Russia. She would also like to have water from the main body of the lake. At the minute, they are only sampling the very top layer, which rises into the borehole during the final phase of drilling. "We believe that life, if it exists, will be deeper," says Lekhina.

Tulaczyk and his colleagues did get a sample of pristine water from Lake Whillans. Admittedly, their task was easier, with far less ice to get through and warmer temperatures to contend with. They didn't need to keep the borehole open with drilling fluid. Instead, they used a hot-water drill – collecting boiling snow at the surface, irradiating it with UV light to kill everything inside, and then pumping it down through the ice. The nozzle and other equipment were also irradiated and washed with hydrogen peroxide. When the team broke through to Whillans on 27 January 2013, it was the first clean drilling into a subglacial lake, says Tulaczyk.

In the water samples they found plenty of evidence for a thriving microbial ecosystem. DNA sequences suggest that the microbes in Lake Whillans are chemoautotrophs, like the ones at Blood Falls. "They get their energy from rocks and mud and stuff underneath the ice," says team member Ross Powell of Northern Illinois University in DeKalb.

On 8 January this year, the team drilled at another location, downstream of the lake. This time the borehole went through the Ross ice shelf, just above the glacier's grounding zone, where the ice lifts off the bedrock and begins floating on ocean water. The researchers lowered a camera down into what is essentially an estuary hidden beneath the ice. They found a lot more than microbes, netting shrimp-like amphipods and spying eel-like fish on their screens. Powell wants to go back and trap them. "It's the ultimate form of ice-fishing," he says.

The big question is what supplies the energy for all this life. The ocean beneath the ice here is dark and 800 kilometres from open water, so the sun is unlikely to be the energy source. Could the entire food chain – all the way up to amphipods and fish – rely on chemoautotrophic microbes?



The Gamburtsev mountains, seen on a radar image through hundreds of metres of ice

ANTARCTICA'S GAMBURTSEV PROVINCE PROJECT

If that's the case, it will be only the second chemosynthetic ecosystem known on the planet, says Tulaczyk, the first being deep-sea hydrothermal vents. Despite being devoid of sunlight, vent ecosystems sustain large animals like tube worms – and it all rests on bacteria that get their energy from chemicals spewing out of the vents. Geothermal and volcanic activity beneath the West Antarctic ice sheet could supply energy for large organisms too, not just microbes. "We haven't found that in Antarctica yet, but it's a possibility that somewhere beneath the ice you are going to find something similar," says Tulaczyk.

"Deep beneath the ice, they found fish and even netted shrimp-like amphipods"

The researchers also want to explore a channel in the bedrock that may carry water from Lake Whillans to the estuary, as it could be bringing nutrients to the area. Powell's team plans to lower a 7-metre-long remotely operated underwater vehicle, bristling with instruments, down a borehole to find out more. "It's a cigar-shaped cylinder when it goes through the hole, and once it gets into the water it goes through a transformer sort of thing and opens up, and swims about in an open configuration," says Powell.

It's not just about finding new life forms here on Earth. Exploring subglacial Antarctica may boost efforts to look for life elsewhere in the solar system, such as on the frozen moons Europa and Enceladus. Both harbour liquid water under their vast icy surfaces. "We don't expect to find a photosynthetically driven ecosystem [there]," says Tulaczyk. "So having a continent that has a chemosynthetically driven system beneath the ice is a nice analogue to pretty much everywhere else that we hope to go and look for life that hasn't originated on Earth."

We have come a long way from the early days of Antarctic exploration. Less than 150 years ago, geologists thought Antarctica's ice was anchored to the peaks of a volcanic archipelago. No one suspected it hid a continent, let alone life. Our image of Earth's seventh continent has changed forever. "It's come alive," says Tulaczyk. ■

Anil Ananthaswamy is a consultant for *New Scientist* based in Berkeley, California

Speaking of culture…

Time to seriously rethink who we are, finds **Alun Anderson**

The Secret of Our Success: How culture is driving human evolution, domesticating our species, and making us smarter by Joseph Henrich, Princeton University Press, $29.95/£19.95
The Crucible of Language: How language and mind create meaning by Vyvyan Evans, Cambridge University Press, £18.99

WITH the year drawing to a close, it's time to throw out old ideas and bring in the new. Two mind-stretching books, *The Secret of our Success* by anthropologist Joseph Henrich, and *The Crucible of Language* by cognitive linguist Vyvyan Evans, will help you do just that.

Both contain powerful ideas. The first forces a rethink of what makes humans special: the answer is not that we are terribly clever or able to do much with our big brains on our own. The second tackles one of the hard problems of science: how it is that language actually means something and can excite our deepest passions.

The two books reflect the same broad trend. Overly simple ideas of "modular", innate human capabilities are fading away – whether of human nature as a toolkit of skills evolved for the key problems we faced during our long ancestry as hunter-gatherers, or of language as an instinct, with a universal grammar encoded in our genes.

Henrich argues that the secret of our success comes from culture, with cultural evolution and genetic evolution driving one another. The result of an immense period of this gene-culture co-evolution is not a "really smart, though somewhat less hairy, chimp", but "a new kind of animal" which has arrived because it is "better to be social than smart".

The story starts over a million years ago, when we first began learning more from past generations than we could possibly work out for ourselves in a lifetime. Unlike all our ape relatives, we had become a species dependent on culture. From then on, Henrich argues, selection began to favour those who were good cultural learners. As we created tools, weapons, fire, cooking and clothing, along with social norms to widen our cooperative life, our genes changed to make us fit better into the world we were creating.

> **"In bringing culture centre stage, Henrich may help heal the rift between social and biological sciences"**

We can see the impact of co-evolution on bodies and minds. Our short colons, small stomachs and tiny teeth are obvious signs of our dependence on cooking. Surprisingly, culture made us the sweatiest species too. Along with longer legs, our abundant sweat glands made us great at long-distance running in the heat, letting us chase prey until they collapse. Culture must have facilitated this, Henrich argues, because we had first to figure out how to make water containers to rehydrate us as we ran.

Our minds have changed, too. The big difference between baby humans and chimpanzees is not in mastering abstract ideas, like quantity or causality, but that we are "prolific, spontaneous and automatic imitators, even willing to copy seemingly unnecessary or purely stylistic steps". Under pressure to keep up with culture, we are built to imitate and fit in.

Once you are persuaded of these basics, Henrich's book will take you on a prodigious journey through human nature and society. A recurring insight is how often cultural evolution creates complex new things without our knowing how, along with norms we over-imitative apes simply obey. Whether it's hunters using bone divination to search for prey, or you or me cooking "the way it's always done", we are following practices which work for reasons we don't understand.

ALEX MAJOLI/MAGNUM PHOTOS

Marriage norms, too, can go unchallenged. Many see it as "natural" that societies strongly disapprove of female infidelity, because a husband may not invest in a child if he is not sure it is his own. But Henrich points us to the Aché people of Paraguay, who encourage women to have multiple male partners, none of whom can be sure of the paternity of the children and so may share their upbringing. Anthropologists report that children survive longer with two fathers rather than one. In Aché society, it is not "unfaithful" women who attract criticism, but men who express jealousy. Culture and genes can

MARTINE FRANCK/MAGNUM

The body is key to how knowledge is represented in the mind

Unlike other apes, we depend on culture and so follow the crowd

find many ways to dance together, and in bringing culture back to centre stage, Henrich may help heal the rift between the social and biological sciences.

The book overlaps with Evans's when Heinrich considers language, which he sees as evolving in a cooperative society and, like other tools, being shaped to meet its users' needs.

Evans would agree. His earlier bestseller, *The Language Myth*, dispatched the idea that language appeared suddenly. In *The Crucible of Language*, he moves on to show how interactional intelligence, symbolic thought, gestures, words and then grammar can appear step by step, as any good evolutionary account would demand.

That is important, but only a part of a remarkable book which, at its heart, tackles the ineffable issue of how it is that language means something. Too often language has been studied as though it were a puzzle of grammatical structure, avoiding the hard question of how it can make us happy, angry or sad.

Evans begins by declaring that language truly is a window on the mind, and that its study can help reveal the structure of thought – brain scanners don't provide all the answers. Then he argues that our bodies are central to how knowledge is represented in the mind; there is no such thing as pure, disembodied reason.

Support for this notion of "embodied cognition" comes from the now classic analyses of linguist George Lakoff and philosopher Mark Johnson. They argued that everyday language reveals abstract thoughts to be structured metaphorically in terms of bodily experiences, with "conceptual metaphors" linking abstract ideas to more concrete ones.

Take these expressions about a rocky relationship: we'll have to *go our separate ways*; we are not *going anywhere*; we're *stuck*. All of them, and many more, use a metaphor of "love" as a "journey", reliant ultimately on the bodily experience of motion. Metaphors don't map in reverse; there are none for "a journey as love".

With help from Evans, you'll see conceptual metaphors everywhere. Of course, basic concepts must have origins, too, and Evans explores the world of a baby and how such concepts emerge. By the midpoint of the book you will feel comfortable with the idea that our minds possess many concepts, rooted in our perceptual bodily experience and independent of language (although language provides a window to explore them).

Then you are ready to see the magic of language. It helps to try Evans's little mind experiment. Think of a "red fox", and then of the actress Gwyneth Paltrow's "kick-ass red lipstick". You will surely see two very different hues in your mind's eye. The word "red" on its own does not take you to the colour "red". Rather, each of these examples reactivates a perceptual experience of different types of red – an "analogue" concept that is rich, vivid and detailed.

"Evans reclaims language from dry dissection and returns it to the public to think deeply about"

For Evans, language allows access to the conceptual system and, with help from grammar, guides the way in which concepts are activated, giving them structure. It is almost as if language instructs your brain to run a particular simulation.

For this to happen, language has to have ways to call up concepts and to direct how they are to be interpreted and presented. Evans takes sentences apart to reveal where these instructions are hiding. You'll see that words are never simple but encyclopaedic in nature, and how language might provide a pathway through this tangle to reach the needed concepts and produce complex meanings.

The ideas Evans presents are new, and we can expect them to be contested. But in attempting a coherent explanation of why language means something, he has reclaimed language from the dry dissection of grammatical structure and returned it to the public as a topic to think deeply about. That is a major achievement in an exciting book. ■

Alun Anderson is a consultant for *New Scientist*

Paint with numbers

Mathematics and art have a long and rich history, discovers **William Latham**

Mathematics and Art: A cultural history by Lynn Gamwell, Princeton University Press, $49.50/£34.95

"CELLS and tissues, shell and bone, leaf and flower, are so many portions of matter, and it is their obedience to the laws of physics that their particles have been moved, molded and conformed. Their problems of form are in the first instance mathematical problems," wrote the Scottish polymath D'Arcy Wentworth Thompson in his influential 1917 book, *On Growth and Form*.

This is a text that the author of the excellent new book, *Mathematics and Art*, has taken to heart and built on. In 500-plus, sumptuously illustrated pages, Lynn Gamwell has interleaved mathematics and culture (art, in particular) from 3000 BC to the present day, as she works to show how artists have harnessed maths for their own creative goals and how the arts, albeit to a lesser extent, have influenced maths.

There are many telling examples. Take Piero della Francesca's 1455 painting *The Flagellation of Christ*, in which he positioned Jesus in a three-dimensional, naturalistic scene rather than an out-of-scale figure on a flat, 2D plane as his early Renaissance predecessors such as Giotto had done. This was a radical and daring innovation. What made it possible was the painter's use of a set of new mathematical rules, which we now call linear perspective, that had been invented by mathematician and architect Filippo Brunelleschi.

Brunelleschi had himself been influenced by an 11th-century Islamic treatise on optics and visual distortion that had helped shape his ideas on perspective. This single mathematical step was to influence the whole of Western art, as exemplified in works by Leonardo da Vinci, Hans Holbein, Albrecht Dürer, Salvador Dali and, of course, M. C. Escher.

"Early Renaissance artists no longer painted saints floating in a golden mist in a faraway place; linear perspective gave them the tool to depict Jesus and the apostles existing right here, right now before their eyes in the natural world," writes Gamwell.

There have been many examples of these mathematical cross-overs: think of Mandelbrot's fractal maths translated into psychedelic-style computer art in the 1980s, or the influence of quantum mechanics on post-modernist painting and sculpture. They may not all be of the same magnitude as Francesca's use of perspective but they are significant, and it's illuminating to discover the background to these innovations.

"George D. Birkhoff attempted to reduce aesthetics to a single mathematical formula"

ANTONY GORMLEY, QUANTUM CLOUD V, 1999, 4 MM SQUARE SECTION MILD STEEL BAR, 274 X 155 X 119 CM. PHOTOGRAPHY: STEPHEN WHITE. © THE ARTIST

Quantum Cloud V is used to discuss quantum mechanics

It's also important to recognise how many mathematical fields inform art. Crystallography, celestial geometry, phyllotaxis, differential calculus – all helped to shape Renaissance art and movements such as surrealism, constructivism, pop art and minimalism.

Mathematics and Art is split in two, with the first section bringing us up to about 1900, and serving as a handbook for readers who want to choose specific topics. Among the mathematical gems and anecdotes, Gamwell cites conversations between da Vinci and Franciscan friar and mathematician Luca Pacioli discussing what would become Pacioli's book, *On The Divine Proportion*. There are also reproductions of John Dalton's rough but extraordinary diagrams of atomic elements from 1806.

The second half, post-1900, has fewer diagrams and works less well as a mathematical handbook. Instead, its strong suit is the presentation of the philosophical relationship between the arts and maths – as when Gamwell discusses the detail of quantum mechanics, taking Antony Gormley's *Quantum Cloud V* (see above) sculpture as her hook.

Gamwell also dives into the compelling area of how we measure aesthetic value, citing George D. Birkhoff's attempts in the 1930s to reduce aesthetics to a mathematical formula, $M=O:C$, or the amount of aesthetic pleasure produced by an object (M) equals the ratio of the object's order (O) to its complexity (C).

This is particularly relevant to the emerging field of creative robotics, where the goal is, apparently, to create a robot that will create art for its own aesthetic enjoyment, emulating the human creative process.

Gamwell must have had her work cut out deciding what to include and exclude in what aims to be a comprehensive tome. There are casualties. In the computation section, for example, it was right to make much of fractal mathematics, Alan Turing, John Conway's Game of Life and computer artworks by Roman Verostko, Manfred Mohr and Yoichiro Kawaguchi. But some classic computer graphic algorithms are missing, such as Ken Perlin's noise texture algorithm or the Blinn-Phong reflection model, which have had a major impact across the arts and in film.

And we really do need more than a brief reference to artist Robert Rauschenberg, composer John Cage and the Experiments in Art and Technology group's show in 1966 at The Armory in New York. The group was set up to foster collaborations between artists and engineers through direct personal contact rather than through any kind of formal process. The creative talents that came together then helped define the work of a generation – and generations to come.

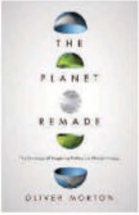
Overall this is a comprehensive, valuable and detailed book. It is written in an accessible style, with enough mathematics to interest the technical reader without overwhelming one with an arts background. It doesn't quite rival Douglas Hofstadter's hugely influential *Gödel, Escher, Bach* from 1979, but its rich anthology is particularly relevant today, given the explosion of interest in the digital arts and the need for digital artists to use maths creatively. I will definitely be keeping it close at hand. ■

William Latham is a computer artist and professor of computing at Goldsmiths College, London

A breath of fresh air

We desperately need to overhaul our approach to climate change, finds **Simon Ings**

The Planet Remade: How geoengineering could change the world by Oliver Morton, Granta, £20



WHO'S afraid of big engineering? Apparently, there exists a global network of activists convinced that aircraft vapour trails are substances sprayed into the air as part of a government programme for – take your pick – mind control, sterilisation or climate management.

All those in this network, and many outside, fear Promethean science. And geoengineering – the idea that we should alter the climate to our advantage while there's still food in the shops and our coastal cities are above sea level – is certainly Promethean.

It is, however, anything but the darling of the military-industrial complex. Its researchers are poorly funded enthusiasts, many of them close to retirement. They do not want to control the climate, and indeed could not, even if they tried. Instead, they want to offer a stopgap technology that will keep global temperatures stable while the gargantuan work of unpicking the carbon economy goes on.

Could geoengineering help buy us time to kick the carbon habit?

BJOERN LAUEN/GETTY

The global consensus on climate change treats carbon as a contaminant. The hope is that enough political will can be mustered to get rid of excess atmospheric carbon, in much the way the world abandoned the chlorofluorocarbons responsible for damaging the ozone layer.

> **"Even the losers in Morton's detailed scenarios would fare better than if we heat Earth by more than 2 °C"**

This is an approach that has been shown to work, but in *The Planet Remade*, Oliver Morton is here to show that it is hopeless: "Any plausible cuts in carbon dioxide emissions made today would have more or less no effect until the mid-century. By that time the costs of inaction might be horribly plain – but there will be no time machine with which to come back and set the necessary cuts in motion on the basis of that future knowledge." Something as complex as the relationship of industrial civilisation to Earth "isn't the sort of thing that is simply solved, once and for all, and it's a snare to think that it is".

Veiling the atmosphere with sulphur could stabilise global temperatures indefinitely for little cost, he believes. It would be another form of climate change and Earth would be a little drier. There might be losers as well as winners. But even the losers in Morton's meticulously detailed and exhaustively referenced scenarios would fare better than if we heat Earth by more than 2 °C. The task would then be to replace the carbon economy.

Naysayers believe that if we were to stabilise global temperatures, we would somehow forget about the carbon problem. But given the fast-declining alkalinity of the oceans, this hardly seems likely.

Morton believes the climate-change debate is hobbled by a bleak view of humanity. The prevailing sentiment seems to be that we will not recognise runaway industrial growth as folly until it has done all the damage it can – and that full recognition of that folly is the only route to avoiding further destruction. "I can't say that there is no wisdom in that stance," writes Morton. "I can only say I do not share it. I refuse to accept a world in which nothing can be protected and only pain and loss instruct."

Over nearly 400 pages, Morton constructs his argument with the intensity of an essayist. It is a dizzying, exhausting, exhilarating read. And let me nail my colours to the mast: he's right. ■

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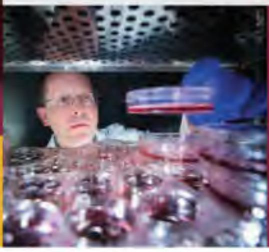

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NOMINATIONS SHOULD INCLUDE

1) A summary of the research on which this nomination is based (no more than 500 words).
2) A summary of the significance of this research in the fields of biology or biochemistry (no more than 500 words).
3) A brief biographical sketch of the nominee, including positions held and awards received by the nominee.
4) A key publication list of up to ten of the nominee's most significant publications relating to the research noted under item 1.
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NOMINATIONS

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EDITOR'S PICK

WE'RE BUILDING A NEW UNIVERSITY ECONOMICS DEPARTMENT
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Ecology precedes economics

From Paul Nieuwenhuis

In your Leader you appear to suggest some kind of equivalence between ecology and economics (21 November, p 5). Surely there is a hierarchical relationship here?

Economic activity attempts to explain the exchange of goods within society, while society itself is embedded in and interconnected with the wider (natural) environment. The economic therefore is embedded within the social, which is itself embedded within the ecological - that "triple bottom line" so beloved of those on the economic side who pay lip-service to the ecological is therefore not truly linear.

Such a scientific understanding is crucially important in a world where many appear to believe that economic laws can somehow override natural laws. The only way to reconcile the economic and the ecological is for the economists to understand their place within this wider ecological context.

It is in fact crucially important that we move away from the current economic understanding of the world and turn instead towards an ecological understanding. Without such a shift we are in trouble.

Cardiff, UK

To read more letters, visit newscientist.com/letters

Can violence be treated as disease?

From Martin Greenwood

I am not convinced treating killing as a disease will work (14 November, p 40). As Steven Pinker wrote in his book *The Better Angels of Our Nature*, for most of human history violence has been much more common than we now take for granted.

What is remarkable isn't that some people kill, but that in the modern world so few do so. Surely, most have wished at times, however fleetingly, to be free to administer summary justice.

Stirling, Western Australia

From Peter Lavers

To understand how a person can be made to overcome an aversion to killing others, look at military training and the inculcation of a belief system that justifies committing violence as being lawfully sanctioned.

Distinguishing between "collateral damage" and "terrorism" requires looking at the objective facts through the prism of a belief system that sanctions one but not the other.

Canberra, Australia

From Meg Daley Olmert

Premeditated murder of all stripes is, at its deepest roots, made possible by the failure to suppress what dog trainers call a "prey drive". I see this as a primal reflex, held in check through social recognition, the most basic and essential form of associative learning. It is social recognition that allows us to see "other as kin", neurobiologically bonding mothers and babies, lovers, and extended families.

This top-down neural social boost has resulted in the hyper-cooperative human societies that have been our most successful evolutionary strategy. But it also leaves us vulnerable to cultural manipulation of who we see as kin. When our brains begin seeing "other as enemy", neurochemical default inhibitions for murder are compromised. That is when people become prey.

Wittman, Maryland, US

Who shall teach the systems?

From Brian Pollard

There seems to me to be a paradox in all this discussion of expert computer systems replacing professionals (21 November, p 42). All the expert knowledge in these systems will have been derived from human "experts". But what happens after the human experts become redundant, and only the encapsulated knowledge remains? How will the computer systems be updated?

In my own field of engineering design, the really useful skill of an expert is to look at an engineering requirement and understand what is important and needs time and resources to address, and what is less important. How is a computer going to get experience of this? There is no body of text it can absorb to tell it what to do.

Great Shoddesden, Hampshire, UK

Computer says no: who loses?

From Steve Tunn

Chris Baraniuk discusses computer algorithms that de-select job applicants (31 October, p 20). Such programs now form a significant part of our lives.

The measurements they purport to make and the actions they indicate are the subject of behavioural sciences. But where, for instance, is the science to justify how human resources departments choose keywords or patterns to track in applications? Where is the science to show that searching for specific words is an accurate and reliable predictor of future performance? In the end those who lose from such unproven tools are the employers as well as prospective employees.

Ingleton, Lancashire, UK

To detect lies, first know the truth

From Jo Spencely

So we now have computers that can spot liars (7 November, p 22). How can we be sure? We are told that algorithms picked out truth tellers 75 per cent of the time – but what they "correctly identified" were those found guilty by juries.

Agreeing with a jury that someone is lying isn't the same as proving they are lying. In the UK alone, just ask the Guildford Four, the Birmingham Six…

Edinburgh, UK

Mass produced bread intolerance?

From Giuseppe Sollazzo

Your article asking whether food is getting less nutritious reports suspicions that the Chorleywood bread-making method could be a cause of the increase in bouts of irritable bowel syndrome (17 October, p 32).

People with the condition often claim it is triggered by bread. I wonder whether the prevalence of the process might also explain at least some of the rather similar cases that are these days widely – and often incorrectly – diagnosed as intolerance to gluten?

London, UK

Neural correlates of consciousness

From Eric Van

In your story "Consciousness theory rocked", you report that a proposed neural correlate to consciousness, the P3b EEG signal, can accompany unconscious as

“Higher prices for soft drinks will create a black market: seedy dealers will cut their product”

Mike Whitey is just one commenter sceptical about a UK proposal to raise sugar prices (5 December, p 7).

well as conscious brain processes (7 November, p 14). But this does not actually undermine global neuronal workspace theory.

I’m not sure anyone expects to find a single neural correlate to consciousness that is both necessary and sufficient for conscious processing to occur; that would be far too simple.

The evidence now tells us that the processes that generate the P3b signal are necessary but not sufficient. That actually represents potential progress in the theory, not damage to it.
Watertown, Massachusetts, US

Schizophrenia, cats and inflammation

From John Stadden

You report research linking schizophrenia to brain inflammation and more active immune cells in the brain (24 October, p 17). Could this high level of immune cell activity be linked to the *Toxoplasma gondii* parasite, commonly transmitted by cats? This has been linked to schizophrenia (30 May, p 42).

I hypothesise that this parasite, which is thought to be found in between 30 and 50 per cent of the population, could be the trigger for the raised activity levels in the immune cells of those affected and is worthy of investigation.
Bridgwater, Somerset, UK

Have stored sperm, will travel

From Gerald Legg

I’ve worked with pseudoscorpions for much of my life and I found the snippet about these amazing arachnids using bats as transport most interesting (14 November, p 17). Hitch-hiking is common in several pseudoscorpion families. It can associate species with temporary or transient habitats, including nests, decaying trees, manure and compost heaps and bees’ nests. Females are the most frequently found travellers.

They have well-developed spermathecae, which store sperm for prolonged periods. On reaching a fresh habitat, they can produce a new population without having males around.
Hurstpierpoint, West Sussex, UK

Coo for the pigeons’ union

From Douglas Dwyer

Thank you for your report on pigeons diagnosing breast cancer (21 November, p 12). Much was made of employing pigeons to spot downed pilots in the ocean and at least one patent was granted, in 1981. I also recall reading about pigeons selecting faulty cigarettes. They are always good for a news item. They need a union and proper reward.
Northlew, Devon, UK

Water, water, everywhere

From Nathaniel Hellerstein

You tracked the trajectory of a water molecule from a crashed comet to being printed on your magazine (14 November, p 30).

As water is a molecule, not an element, when it is in liquid form, it can and does dissociate into OH- and H_3O+ ions; then it swiftly reassociates, but with different atoms. What is the half-life of an individual water molecule, in pH 7 solution at room temperature?
San Francisco, California, US

Go fast and multiply

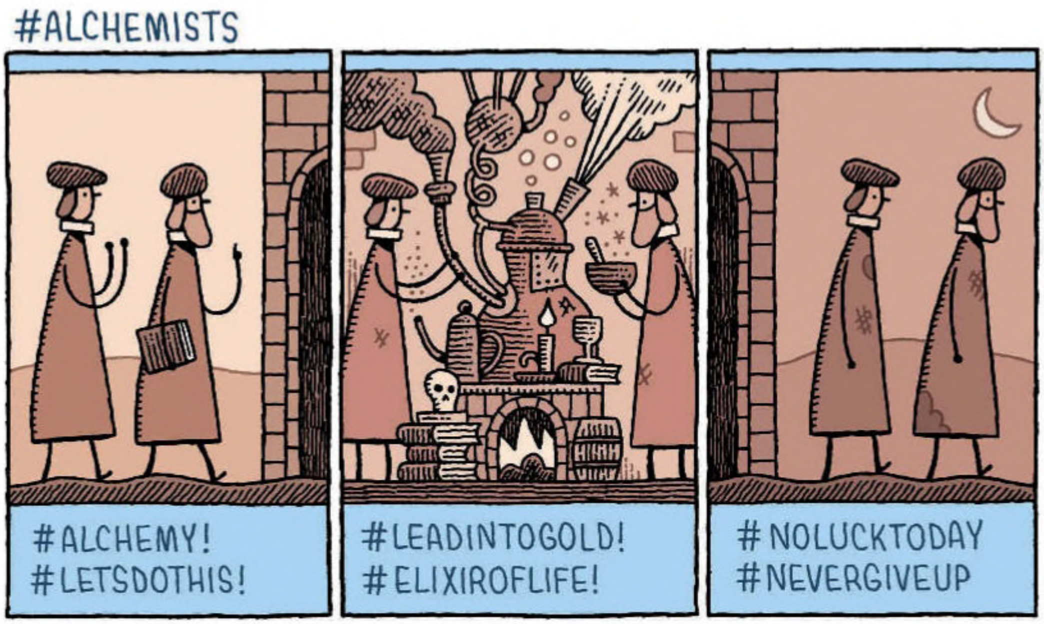
From Eric Kvaalen

You state that calculating the product of two numbers, each having n digits, requires about n^2 steps (21 November, p 11).
But while this is true for basic multiplication, there are algorithms that for large numbers take on the order of n(log n)(log log n) steps. There are algorithms that are even better for very large numbers. It isn’t known what the true complexity is.
Les Essarts-le-Roi, France

For the record

- **William Kirby’s letter about siting nuclear plants by the sea should have referred to our being committed in 20 years’ time to the risk of catastrophic sea level rises in a century or more (28 November).**
- **Watt’s that? The energy used by a Google web search is 0.3 watt-hours or 1000 joules (7 November, p 44)**
- **It was in 1844 that historians proposed that the Black Death was a flea-borne bacterial disease; and the correspondence suggesting its use in the siege of Heraklion ended in 1651 (28 November, p 15).**

TOM GAULD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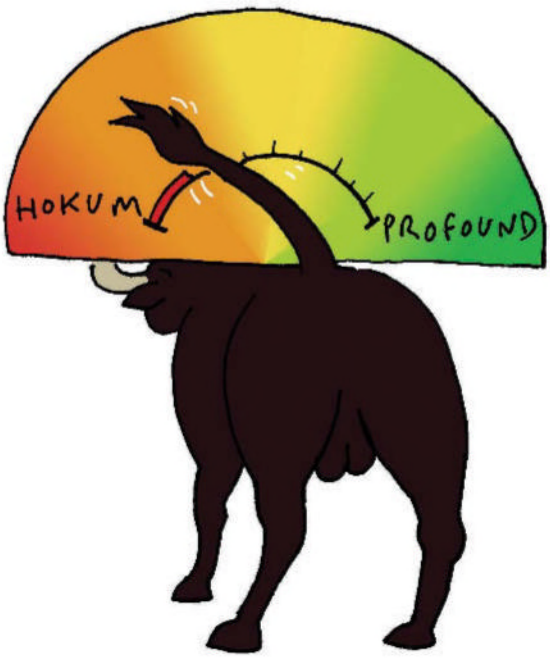


PAUL MCDEVITT

A DECADE after Harry Frankfurst's celebrated treatise *On Bullshit*, we are finally rewarded with a scientific investigation of the subject.

"On the reception and detection of pseudo-profound bullshit" is a paper in which Gordon Pennycook and his colleagues attempt to identify behaviours that render people susceptible to nonsense.

The authors define bullshit as a statement that "implies but does not contain adequate meaning or truth". To form a Bullshit Receptivity scale, they used satirical sites such as wisdomofchopra.com (a random phrase generator trained on the online excretions of guru Deepak Chopra) to create vapid, portentous-sounding aphorisms, which were then judged by participants for profundity.

The authors found that those who judged this bullshit as profound were more likely to hold a belief in the supernatural, among other variables. "A bias toward accepting statements as true may be an important component of pseudo-profound bullshit receptivity," add the authors. To which Feedback says: no shit!

PREVIOUSLY Feedback discovered that Bombshell, a perfume from Victoria's Secret, doubled as an effective mosquito repellent (28 November). "I hope the authors included Avon's Skin so Soft among the alternative insect repellents they tested," writes Vera Silberberg. "Although Avon did not intend it as such, it is now marketed as a pleasant smelling and effective insect repellent, much appreciated by walkers."

Richard Holden concurs: "On our travels to midge-ridden west-coast Scotland we've always taken Avon Skin so Soft. Leaves hands dangerously slippery but stops the little nibblers nibbling."

Rumour has it that even Britain's elite soldiers, the SAS, make use of the balm – although whether this is for its repellent or skin-softening properties we don't know. Will Bombshell's floral tones now join the fragrant arsenal of these fighters?

A manual for an electric scooter warns Ian Moseley not to use the battery contained within if he: "1. Emits some smell or high fever," or "2. Leaks out of any material"

AN AUTOMATED response from the Australian Department of Infrastructure and Regional Development was sent to Marco Overdale. It reads "If your email has been received by the Vehicle Imports inbox you will receive an automated email receipt. If you do not receive this, your email has not been received."

Marco assumes this email is the response he is supposed to receive, but how would he know if it isn't?

DOES your drinking water lack harmony? If so, the seven wave-form rings of the Amezcua Bio Disc 2 can help, we are told. Spotted by John Boyle, this device – cleverly disguised as a glass coaster – will energise bottles of water, improve plant growth, preserve your vegetables and more, when placed nearby.

Shining a torch through the coaster onto your food will make it taste better, with Amezcua keen to point out "Photons – the concept of the basic units of light developed by Albert Einstein – and their interaction within and on biological systems is a long established field of scientific study." Who could disagree?

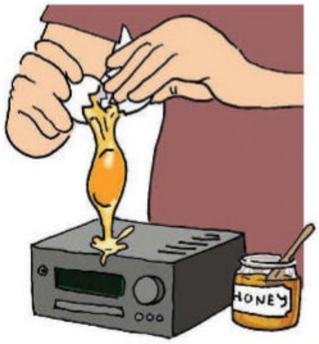
A LONG gestation: fans of nominative determinism should pause to mark the retirement of Richard Bump, who, after 16 years and 2573 manuscripts, is stepping down from his post as Associate Editor for the *American Journal of Obstetrics and Gynecology*.

READER David Rapley recently acquired a new Epson printer, which came with a thorough warning leaflet. Advice to "keep this product at least 22 cm away from cardiac pacemakers" is undoubtedly useful, yet Epson doesn't stop there: "Do not use a telephone to report a gas leak in the vicinity of the leak," it adds.

"This bears no relevance to risks from a printer," ponders David, "so far as I know, they don't contain pressurised gas canisters." He notes that the company's slogan is "Exceed your vision" – in this case, Epson certainly did.

WHILST looking for hi-fi components online, Derek Woodroffe stumbled across a unique collection at Studio Zèy, whose stock can only be described as "artisan". The VNM Capacitor, for example, consists of a capacitor wrapped in linseed oil-soaked silk, glued into a wooden cube with beeswax and sealed with *vernice bianca*, a varnish made of egg whites, honey and sugar "rumoured to have been used by Stradivarius in his legendary violins".

The "Invistor", meanwhile, is a resistor made with ebony wood and silk, although because it "passes on the full dynamic range of the signal, while being completely transparent itself", it may not be the best resistor.



Studio Zèy warns it will not be liable for any damage arising from the Invistor's use "in electric devices or elsewhere," adding "don't even think of installing them in military or medical machines".

"I've seen many websites that claim to improve your hi-fi with gold cables and exotic components," remarks Derek, "but this really takes the biscuit". To which Feedback says: don't give them any more ideas.

You can send stories to Feedback by email at feedback@newscientist.com. Please include your home address. This week's and past Feedbacks can be seen on our website.

Clucking on

Why do hens cluck loudly after laying an egg?

■ I have kept domestic fowl free-range for almost 60 years, namely bantams and silver-laced Wyandottes.

This is what I have observed: a hen enters the nest 10 to 20 minutes before laying and settles herself. She stands to lay the egg, which is soft-shelled and hardens on contact with the air. She then sits quietly for a few minutes, preening, crooning and resting.

The hen then jumps up from the nest with a loud cackle and, given the freedom of the range, runs a considerable distance. The dominant rooster hears the cackling, runs with wings outstretched to the hen and mates with her immediately. He then performs a "stamping" display and both go off happy. So it seems that the cackle helps to attract the rooster to mate once an egg is laid.

If there are rival males, the rooster will patrol outside the nest like any expectant father, and then mate with the hen as soon as she has finished laying. In that case, the cackle may be quiet to non-existent.

When mating at other times, the stamping display comes beforehand and there is no cackling.
Nina Dougall
Malmsbury, Victoria, Australia

Treading lightly

By UK law, car tyres must have a tread at least 1.6 mm deep. It is about 9 mm on my new tyres. At what point would deeper treads worsen road holding and why?

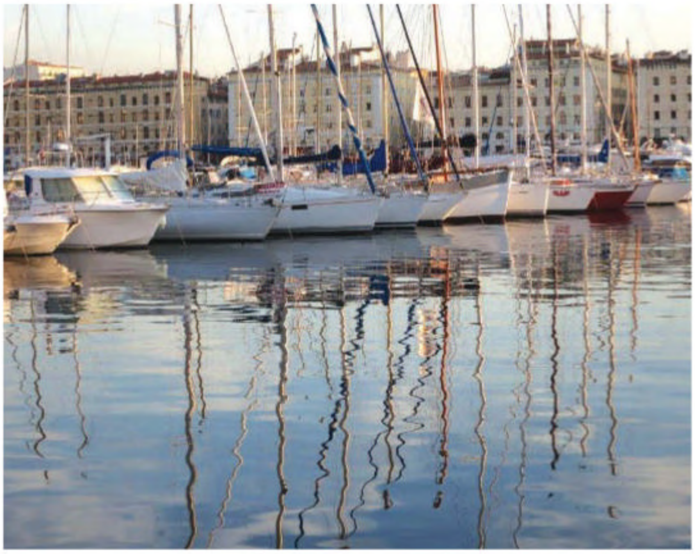
■ Tyres do not need grooves to improve grip in dry weather. This is demonstrated in motor racing, in which smooth "slick" tyres are the rule. These are used unless it is wet, when the addition of grooves allows a tyre to squeeze away water that would otherwise lubricate it and remove grip. The heavier the rain, the deeper and more numerous the grooves.

New road tyres have sufficient grooves for all but very heavy rain. But as they wear, their capacity to shift water drops because the grooves become shallower, until they are insufficient even for light rain – which is the limit for legal tyres as noted in the question (with a safety margin added).

The deeper the grooves, the less grip the tyres have because less rubber touches the road and the parts between the grooves move about. So on a dry road, any groove inhibits grip. But unless you can do a pit stop as soon as it rains, you are still better off with grooved tyres for road use, purely to ensure you can drive in all conditions.
John Davies
Haverbreaks, Lancashire, UK

■ The maximum tyre tread before the ride becomes too rough depends on the kind of road on which you're driving, and what suspension you have. Bicycle tyres are a good example – a thick knobbly tyre grips mud and loose terrain well, but is heavy and noisy on tarmac. The heavy tread means that it won't rebound so quickly to the relatively small stones on the road, so its grip is poor. Modern tyres on racing bicycles are thin and light. The tread layer has low mass so it can follow small road undulations, providing good grip. Because the internal pressure of the tyre is high, it pushes through any water, so even slick tyres grip well in the wet. On a good road you can do over 40 miles per hour in comfort. But the tyres have zero grip on slimy mud when cycling.
Simon Dales
Oxford, UK

> **"The deeper the grooves, the less tyres will grip because less rubber touches the road"**



This week's questions

TOTAL RECALL
When I can't remember something, how do I know that I ever knew it in the first place?
John Ripley
Leeds, West Yorkshire, UK

SHIVERING TIMBERS
This photo was taken at Vieux Port in Marseille, France. Can anybody explain why the distribution of ripples varies so much that some of the mast reflections have large "waves" in them, whereas others are almost straight?
Clive Wilkinson
Townsville, Queensland, Australia

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